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Waialua Agricultural Co.	*	W. W. Goodale	Waialua
Kahuku Plantation Co.	x*	Andrew Adams	Kahuku
Waimanalo Sugar Co.	**	G. Chalmers.	Waimanalo
Oahu Sugar Co.	x	E. K. Bull	Waipahu
Honolulu Plantation Co.	**	J. A. Low	Aiea
Laie Plantation	x*	S. E. Wooley	Laie
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KEY.	HONOLULU AGENTS.	
	Castle & Cooke	(5)
**	W. G. Irwin & Co.	(8)
***	J. M. Dowsett	(1)
x	H. Hackfeld & Co.	(9)
*x	T. H. Davies & Co.	(8)
**x	C. Brewer & Co.	(6)
x*	Alexander & Baldwin	(6)
x**	F. A. Schaefer & Co.	(2)
x*x	H. Waterhouse Trust Co.	(2)
‡‡	Hind, Rolph & Co	(2)
xx	Bishop & Co.	(1)

THE HAWAIIAN PLANTERS' MONTHLY

PUBLISHED FOR THE

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WEATHER AND CROP.

Typical spring weather—warm, sunny days, and cool, showery nights, have marked weather conditions for the past month; temperatures were about normal for this period of the year.

In windward districts there has been an abundance of rain, but in the leeward parts of Hawaii and Maui the dry spell has continued and drought conditions prevail. On the plantations in Central Maui there was necessity for constant pumping.

Harvesting, grinding and planting operations have proceeded satisfactorily.

SUGAR PRICES MONTH ENDING JUNE 19, 1906.

	Centrifugals.	Beets.
May 15	3.42¢	8s
May 22	3.42¢	7s 10½d
May 29	3.45¢	8s
June 5	3.45¢	8s
June 12	3.47¢	8s 0¾d
June 19	3.50¢	8s 1½d

Under date of June 8, Messrs Czarnikow, Macdougall & Co. say:

"The raw sugar market has been tame and uninteresting throughout the week, the business done being very small for the time of year; but in spite of this the few transactions were sufficient to establish an advance of .02c. in spot sugars, the quotations for which are now as follows: Centrifugals, basis 96°, 3.47c.; Muscovados, basis 89°, 2.97c.; molasses sugars, basis 89°, 2.72c. At the close the market was very firm.

The sales of so small a quantity as 10,000 to 11,000 tons Porto Ricos and Cubas, for shipment this month, were sufficient to fill the very moderate demand for sugars in that position, and further offerings of June shipment cannot, for the present, be placed. Refiners' enquiries have shifted to sugars for July shipment, of which they have, so far, secured very little, and it would seem that if they do not become heavy purchasers of July Cubas and Porto Ricos, they will require to draw a large part of their July-August supplies from their reserve stocks in store.

The cause of refiners' indifference to June offerings is apparent from this week's exports of 42,800 tons from Cuba alone, the greater part of which comes to the Atlantic ports, and will be supplemented by some arrivals from other quarters. Meanwhile, from the standpoint of sellers, the statistical position on this side of the Atlantic is improving, the united stocks in Cuba and the Atlantic ports showing a decrease of 33,000 tons in the week.

Cuban production is rapidly diminishing, and the number of estates in operation is reduced to 68—a decline of 112 from the maximum of some weeks ago.,

The Cuban figures up to the end of May show a total production to that date of 1,055,000 tons, as against 1,034,000 tons up to the end of May last year. As more estates are still at work than were at work at this date a year ago, it is evident that this season's crop will show a moderate increase over that of last season, which reached a total of 1,163,258 tons.

An unexpected decline yesterday in the European beet market created some disquietude in the minds of sellers. It only amounted to 1½d., but it was feared that it might be the precursor of greater weakness. Fortunately the decline was only temporary, and today's quotations mark a return of confidence. They are: June, 8s. 0¾d.; July, 8s. 1½d.; August, 8s. 2½d.; September, 8s. 2¾d. New crop, October-December, 8s. 4¾d. These quotations show a fractional advance upon those of last week. The June price of 8s. 0¾d. f. o. b. is equal to 3.67c. for Centrifugals, basis 96°, and prompt beets are consequently .20c. above the selling parity of cane sugars here.

There have been no May shipments of Javas to America or Europe. Last year the May shipments were 9,200, and they were 8,000 tons in 1904. The June shipments to America and Europe are likely to fall considerably short of those of June last year, which were 85,000 tons.

There have been rumors of sales this week, to United States buyers, of Javas for June-July shipment, and it is probable that something has been done, although all particulars are withheld. Prices show a hardening tendency, and offerings are few in number and small in quantity."

Messrs. Willett & Gray in their "Weekly Statistical" of June 7, report:

"The week under review opened rather firmer, with sales of nearby sugars at 3.47c. for 96° test, against 3.45c. paid a week ago. Cuban Centrifugals for shipment second half June were placed at 2.09c. c. and f., basis 95° test, equal to 3.48c. landed for 96° test.

Toward the close the market developed some unfavorable signs, but leading to no special changes in actual conditions.

European markets ,after several holidays, opened with a weaker tone and tendency, ending in a reaction to 7s. 11¼d. for prompt beet, or a decline of 1½d. for the week.

Cuba exported so largely to the United States this week that refiners became indifferent buyers for the present at least and, while concessions are not named by sellers the quantity offering at current quotations is considerably on the increase for this month's shipment. July offerings,. however, are still limited and quotations firmly held.

As Cuba is now in a position to take care of the balance of crop without forced concessions, all interest in the future centers about the European situation.

The present weakness of the markets over there is suggestive of several possibilities, one of which may prove in the end to be the liquidation of much beet sugar now being carried along at a cost of 9s. or more. But as European parity is still .17c. per pound above Cuba the latter market need not be very materially influenced by anything that might occur in Europe unless of an extraordinary nature.

Cuba and the United States working together and leaving Europe out of consideration are in a good normal condition for steadiness and a moderate improvement, which must continue unless European complications come to a focus is an important decline.

The situation abroad needs careful watching for some time to come.

In Cuba 20 Centrals finished grinding, leaving 68 still in operation, against only 17 at same time last year.

The weather is reported with frequent rains over the island, and with the final rainy season set in for good in many localities.

The total receipts at all ports in Cuba to May 31st amounted to 1,055,181 tons, and the stock in the island on that date was 323,206 tons, against 1,034,280 tons and 381,509 tons, respectively, at same time last year.

Rumors are current of large sales of Javas to American refiners, but these reports lack confirmation. It is just possible, however, that one cargo has been placed here, and the price is believed to be a shade over 8s. 6d. c. and f. Sellers are now asking 8s. 10½d. c. and f. for shipments from Java during July-

August, equal to 3.66c. landed for 96° test, which is much above buyers' views.

Our special cables just received from Batavia report no exports from Java during May to Europe and America, and only 1,000 tons elsewhere. The harvesting of the new crop is proceeding favorably."

Mr. F. O. Licht's "Monthly Report" of May 18, contains the following in reference to the beet sugar interests:

According to the *Inquiry Results* of the "International Statistics Union" the, this years' area cultivated with beets against the preceding years amounts to:

	1906-07	1905-06	1904-05	1903-04	
Germany	440,340	467,885	414,802	415,856	hectares
Austria	342,100	371,500	322,100	309,100	"
France	190,300	262,866	203,772	236,874	"
Russia	594,227	538,544	478,463	525,100	"
Belgium	59,820	71,385	45,800	59,150	"
Holland	44,075	48,480	35,856	40,345	"
Sweden	30,300	27,750	24,149	27,378	"
Denmark	15,200	15,200	14,000	14,000	"
Also other countries	89,000	98,000	88,000	94,000	"
Total	1,805,362	1,901,610	1,626,942	1,731,803	hectares

Without the so-called "other countries" for which the figures have been given on our part the European beet area of 1,716,362 ha, against 1,803,610 ha in the preceding year will show a decrease of 4.8%. In May, 1905, on the occasion of the previous year's "inquiry" the cultivated area for 1905-06 was assumed by the "International Statistics Union" at 12,632 lower than the present contrasting figures published by them, indeed, in the case of France alone the difference is, in round numbers, 16,000 ha, by which amount, the previous year's cultivated area in France seems to be higher. For the chief countries: Germany, Austria, France, Belgium and Holland together, there is a decrease of 11.9% against the preceding year; whether, however, it is right to attach only a secondary importance to the remaining beet growing districts, especially Russia and its cultivated area, may be reasonably doubted, as should Russia, by means of a normal harvest, again be in a position to export great quantities of sugar to the districts which it has, till now, principally supplied, viz.: Persia, Turkey, the Levant, Japan, China, etc., the possibility of transactions there for German, Austria, French and Belgian sugar must be relatively lessened—and it is sufficiently known ,that next to India, just the Asiatic African countries mentioned have considerably contributed and still contribute to the increase in the export figures of the productive convention towns in the current year. Further, for instance, it is natural, consequence that, hand in hand with an increased produce of one's own, a lesser need for foreign sugar must step in. On the other hand one must not overlook the fact that in Russia, the produce of the plots is regularly under that of the Middle and West European countries (the sugar gain from the hectar amounted, according to the six years average in Russia, only to 2,049 tons; in Germany, on the contrary, 4,496 tons), and that the inner political and social conditions of Russia are still unusual.

The medium of the figures given in our "Monthly Report" of the 17th of April of this year for the cultivated area is, as is already known, placed, including the "other countries" at 1,788,-750 ha while, as may be seen from the above figures the "Inquiry" of the "Union" gives 1,805,362 ha. Without the "other countries" the average of our area figures published before the space of a month was 1,698,750 ha and the equivalent figures of the "Union" were only 17,600 ha higher, that is to say, 1,716,-362 ha.

The consumption in the various countries was as follows

	1906	1905	1904	1905-06	1904-05	1903-04
	In the month of April.			In the 8 months, Sept.-April.		
	Tons	Tons	Tons	Tons	Tons	Tons
Germany ...	86,210	69,355	72,429	721,551	634,839	751,131
Austria	38,408	34,208	35,518	340,419	292,038	338,515
France	48,887	38,549	48,427	431,837	418,592	550,236
Holland	7,745	6,659	6,230	63,220	59,863	68,629
Belgium	5,554	4.060	5,730	55,238	52,394	66,237
England	122,098	121,405	178,806	1,149,559	1,031,179	1,007,404
Total ...	308,902	274,236	347,140	2,761,824	2,488,905	2,782,152
America	147,584	124,689	162,680	1,154,466	1,153,239	1,130,743
Total ...	456,486	398,925	509,820	3,916,290	3,642,144	3,912,895

From this there results that in this April alone, when compared with the same month of the preceding year, 57,561 tons (14.4%) more were consumed; when compared 1904, 53,334 tons, 10.5%) less was consumed; while the increase for the period commencing with September 1st amounted to 274,146 tons (7.5%), and 3,395 tons (0.1%).

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A NEW NITROGENOUS FERTILIZER.

Editor Planters' Monthly:

Considerable interest is developing among English and German agriculturists in a new nitrogenous fertilizer, Calcium cyanamide, which some believe may take the place of sulphate of ammonia, as it can be manufactured at a much lower cost.

Calcium cyanamide is an artificial manure containing nitrogen derived from the air. The starting point in the manufacturing process is calcium carbide, the well-known substance from which acetylene gas is generated. The calcium carbide is reduced to a coarse powder, placed in a vessel resembling a gas retort, and brought to a temperature approaching white heat, when a current of nitrogen gas is lead over it until combination ceases. The resulting product is crude calcium cyanamide, a compound containing nearly 20 per cent. nitrogen. The nitrogen required in the process is obtained directly from the air by passing a current of air through a heated cylinder packed with copper turnings. The oxygen combines with the copper and the nitrogen passes into a gas tank until required. The copper is regenerated by passing a current of coal gas through the heated cylinder.

Crude calcium cyanamide is a fine black powder, which decomposes rapidly when heated with water under pressure, and slowly, with water at ordinary temperatures, into calcium carbonate and ammonia.

A plant is being operated in Berlin capable of turning out one ton per day, and others are being erected. The essential feature of this new manufacture is cheap electricity as developed by waterfalls, for the electric furnaces used in producing calcium carbide from a mixture of lime and coke.

Experiments are being conducted at Rothamstead and at some of the German experiment stations to determine the availability of the ammonia derived from calcium cyanamide for the growth of crops.

Prof. A. D. Hall, who reports in regard to some preliminary experiments at Rothamstead in the Journal of Agricultural Science, says that: "There can be little doubt that calcium cyanamide is an effective nitrogenous manure, though more extended experiments are necessary to decide whether the unit of nitrogen is worth more or less than in the case of sulphate of ammonia."

It looks very much as though we are now to realize the long-sought ideal of replenishing the fertility of the soil from the vast store of nitrogen present in the atmosphere.

JARED G. SMITH.

COMPARATIVE TEST OF WATER-DRIVEN AND BELT-DRIVEN CENTRIFUGALS AT EWA MILL.

Mr. Geo. F. Renton, Manager Ewa Plantation Co.

Dear Sir:—The accompanying figures are the results of the comparative test of water-driven and belt-driven centrifugals made at Ewa Mill, August 8th to 11th, inclusive.

While making this test, great care was taken to have, as nearly as possible, the same quality of massecuite to dry,—in each case No. 3 of low purity, which was rather sticky and dried slowly.

When making No. 3 we generally have ten cooler cars of massecuite per strike. Halt of each strike (five cars), was therefore given to each set of centrifugals.

Massecuite was sampled, at each third machine, from the mixer gates.

A sample of molasses was taken every twenty minutes from the flume directly behind the centrifugals.

The belt-driven machines proved superior in almost every way. While the belt-driven machines would be running full speed in less than one minute after starting it took the water-driven machines from five to ten minutes to reach full speed.

Also the belt machines dried more sugar, using less fuel oil in a given time, drying the sugar better, and discharging the molasses of lower purity than the water-driven machines. Furthermore, a much larger quantity of sugar crystals passed through the screens of the water-driven machines; which fact may be readily proved by the fact that the percentage of recovery of raw sugar on weight of massecuite was 5.7% greater in the case of the belt-driven machines. This is probably due to the rapid start of the belt-driven machines which cakes the sugar more rapidly to the side of the machines, thereby preventing much small grain from passing through with the molasses.

This advantage of a rapidly-starting machine is directly contrary to the claim made by Watson, Laidlaw & Co. in favor of a slow-starting machine for drying second sugars:

TABLE "A."

40″ Water-Driven.

Date	Duration of Test	Motive Power	Boiler Pressure per ″	Temp. of Feed Water	No Oil. Burners Used	Gallons Fuel Oil Burned
Aug.	8—10 hrs.	20″x10″x10″ 3 Duplex Pumps working as compound.	120 lbs.	178°F	2	575
Aug.	10— 8 hrs.	20″x10″x10″ 3 Duplex Pumps with direct steam.....	100 lbs.	180°F	2	637

30″ Belt-Driven.

Date	Duration of Test	Motive Power	Boiler Pressure per ″	Temp. of Feed Water	No Oil. Burners Used	Gallons Fuel Oil Burned
Aug.	9—10 hrs.	Corliss Engino 16″x36″	120 lbs.	180°	1	343
Aug.	11—10 hrs.	Corliss Engine 16″x36″	120 lbs.	182°	1	361.37

TABLE "B."

40″ Water-Driven.

Date	No. of Centrifugals	Water Pressure at Pumps	R. P. M. of Centrifugals	Size of Screen	Lbs. Sugar Dried per Gallon Oil Consumed
Aug. 8—	13	180-200	800-900	00	16.5
Aug. 10—	13	200-210	850-950	00	12.9

30″ Belt-Driven.

Date	No. of Centrifugals	Water Pressure at Pumps	R. P. M. of Centrifugals	Size of Screen	Lbs. Sugar Dried per Gallon Oil Consumed
Aug. 9—	32		1400	00	47.7
Aug. 11—	32		1400	00	42.6

TABLE "C."

40″ Water-Driven.

Date	Purity M'c'te	Purity Mol.	Lbs. Molasses	Lbs. Sugar	Recovery of Raw Sugar	Pol'n of Sugar
Aug. 8—	48.4	40.	70.308	17,750	20.16	78. °
Aug. 10—	47.2	37.7				77.4°

30″ Belt-Driven.

Date	Purity M'c'te	Purity Mol.	Lbs. Molasses	Lbs. Sugar	Recovery of Raw Sugar	Pol'n of Sugar
Aug. 9—	47.7	36.6	91,016	31,750	25.86	79.4°
Aug. 11—	47.7	35.4				78.5°

In favor of the belt-driven centrifugals the following points will be noted:

Lower purity of molasses from approximately identical massecuite (2½% to 3½%).

Larger percentage of recovery (5.7%).

Increase in polarization (1% to 1½%).

Large increase in pounds sugar dried per gallon of oil consumed (approx. 30 lbs. per gallon).

NOTE.—The same Babcock & Wilcox boiler was used in all four tests, having been fired with other fuel, and having steam up before starting test, so as not to interfere with the measured quantity of fuel oil. Although the two oil burners were unable to keep up steam when the direct acting steam pumps were used; when the pumps were compounded a great saving of fuel resulted.

The third test had to come to a close at the end of eight hours on account of the oil supply tank being of insufficient capacity to hold enough fuel oil to continue.

The result of the four tests shows a very extravagant use of power, steam, fuel, as well as inferior qualities as a sugar dryer on the part of the water-driven centrifugal.

(Signed)	H. G. BOSWELL,	Engineer.
(")	T. O'DOWDA,	Sugar Boiler.
(")	F. E. GREENFIELD,	Chemist.

FERTILIZERS IN HAWAII.

BY J. T. CRAWLEY, *Manager Hawaiian Fertilizer Co., Ltd.*

Read before the Honolulu Engineering Association at its June, 1906, meeting:

When I was invited to address your body on the subject of fertilizers, I replied that fertilization is a subject for the agriculturist and chemist rather than for the engineer, and doubted my ability to interest you. But looking at the objects of your association from a broad standpoint, a part of which are to instruct your members along all lines that tend to make of them the most useful in industrial pursuits; and remembering that we are all either directly or indirectly interested in sugar, and that fertilization plays a very important part in the production of Hawaiian sugar, it would seem that a discussion of the reason for fertilizing, together with present practices, may not be out of place.

The problems for the engineer in the fertilizer business are in the mining or preparation of the raw material for market, and as little of this work is done in Hawaii, the problems here are more of a chemical than an engineering nature.

The present paper will be along the following lines:

1.—The reasons for fertilizing.

2.—A consideration of the chief raw materials entering into the preparation of mixed fertilizers, with brief description of their sources and methods of preparation.

3.—The development of present methods of fertilizing in Hawaii.

I. THE REASON FOR FERTILIZING.

Plants derive their sustenance from two sources, the air and the soil. From the air they derive chiefly carbon and oxygen which go to make up, in various combinations with each other and with other elements, the complex organic substances of the plants. With these elements we have little to do since nature furnishes an abundance of them, if only the plant is in a condition to take up and assimilate them. From the soil they derive chiefly the inorganic substances which compose the ash when they are burned. Ordinarily soil is of use primarily as a setting or support for the plant, the roots of which spread out among the particles of soil and brace or ballast themselves. The soil is also the source of the ash-forming substances, which though small in quantity, are exceedingly necessary to the development and life of the plant.

It is also the chief deposit of nitrogen, a very important element in plant growth, as we shall see, but that is volatilized on burning and is therefore not found in the ash in any considerable quantity. To show the dependence of sugar cane upon the soil as a source of its food, I give below the chemical composition of a good cane soil, and of the ash of the sugar cane.

Chemical analysis of a dark red soil:

	Per cent.
Combustible or volatile matter (including nitrogen)	12.156
Silica	27.670
Titanium oxide	6.711
Phosphoric acid (P_2O_5)	0.322
Sulphuric acid (SO_3)	0.332
Carbonic acid (CO_2)	0.193
Oxide of iron	26.212
Magnesia (MgO)	0.659
Oxide of aluminum	23.717
Lime (CaO)	0.500
Manganese oxide (Mn_3O_4)	0.277
Potash (K_2O)	0.512
Soda (Na_2O)	1.139
	100.400

Chemical analysis of the ash of white bamboo cane:

	Per cent.
Silica	24.25
Phosphoric acid	8.05
Sulphuric acid	8.16
Chlorine	6.07
Carbonic acid	1.56
Oxide of iron	0.97
Oxide of aluminum	3.98
Lime	5.78
Magnesia	6.15
Oxide of manganese	0.05
Potash	33.08
Soda	3.20
	101.30
Correction for chlorine	1.36
Total	99.94

It is thus seen that the plant takes up practically every substance found in the soil, and we may conclude that all of these substances are necessary to the full development of the cane. But this plant, as will be seen from the table, takes up the elements in very different proportions, also in a very different proportion from that found in the soil. Taking 3,500,000 pounds as the weight of an acre of soil to the depth of one foot, an acre of soil of the analysis given would contain the following number of pounds of the given substances per acre:

Weight of elements in one acre of soil to the depth of one foot:

	Pounds.
Silica	968,450
Phosphoric acid	11,270
Lime	17,500
Potash	17,920
Soda	39,865

Now the ash of the White Bamboo is about 3% of the weight of the cane, and a crop of 50 tons of cane would remove 3,000 pounds of ash, composed as follows:

Amount of mineral ingredients removed by one crop of White Bamboo cane:

	Pounds.
Silica	727.5
Phosphoric acid	241.5
Lime	173.4
Potash	992.4
Soda	96.0
All others	769.2
Total	3,000.0

Now we come to the simple proposition that if one crop of cane removes 727 pounds of silica from a soil that contains 968,450 pounds in the first foot in depth, this soil contains enough silica in this one foot for 1,332 crops, likewise this soil contains enough lime for 100 crops, phosphoric acid for 47 crops, potash for 18 crops, and soda for 415 crops. The case is really much more complicated and not so susceptible of calculation as is outlined above, for the reason that by far the greater part of the soil ingredients are insoluble, or unavailable to the plants, and one soil will differ very materially from another in the availability of its elements. Again, the roots of the cane extend more than one foot in depth in search of food, and the total depth to which they may reach depends largely upon physical conditions, such as porosity of the soil, amount of moisture, etc. Finally, as the available elements in the soil are depleted the insoluble elements are gradually rendered soluble and available to the cane, and this rate of change depends upon many factors, some of which are within, and many beyond our control.

Looking back at our table of the chemical composition of the soil, and of the cane, there are certain elements, as lime, phosphoric acid and potash, which are found in the soil in small amounts, but which are taken up in large quantity by the cane.

This is true not only of Hawaiian soils, and Hawaiian plants, but of most cultivated soils and of most cultivated plants. Indeed, by experimenting in many parts of the world and with many different plants, it has been found that these elements, lime, phosphoric acid and potash, together with nitrogen, are the main deficiencies of most soils, and the substance required by most plants. Some special plants require special elements, and certain soils may be deficient in elements other than those given; as for instance, it has been found in Japan that a little manganese added to the soil enhances the value of the rice crop; but it may be stated as a general proposition that wherever the subject of fertilization is being studied, whether by the various experiment stations of the world, or by the farmer himself, it is to find out in what proportions, and under what conditions these four substances, lime, phosphoric acid, potash and nitrogen are to be used. These then are the chief elements of fertilization, and we fertilize because crops remove large quantities of them, and most soils are deficient in them.

All cultivated soils contain some quantity of each of these elements, but often either in such small amount, or in such an unavailable condition that fertilization is required.

2. RAW MATERIALS.

a Phosphates.

Phosphates are found in many countries and in very large quantities, the chief sources at present being South Carolina, Florida and Tennessee, in the United States; Canada, Algeria and the islands of the Pacific ocean. It is conceded that most phosphate deposits are of animal origin, and we know that the phosphates of the Pacific ocean islands are of bird origin. South Carolina and Florida have for many years been the chief sources of phosphates for manufacturing purposes, both in the United States and Europe, and they have controlled the world's markets. Of late the production in South Carolina has fallen off very greatly, but the deficiency has been more than made up by the comparatively new fields in Tennessee. In South Carolina the land phosphate consists of nodules of an egg or kidney shape, varying in size from that of a pea to that of a potato. Many large masses are found, but these are conglomerations of these smaller bodies. They are found in layers from a few inches to five feet in thickness, the average being perhaps rather more than a foot; these layers being covered with a layer of earth, in some cases so deep as to render mining unprofitable; at other times but a few inches below the surface. A stratum of one foot in thickness will yield 600 to 800 tons of phosphate per acre, though there have been cases in which the yield has run into the thousands of tons per acre. A great number of fossil teeth and bones are found in this phosphate-bearing bed, so that there seems little doubt of its origin. There are various methods of removing the overburden of soil and clay; in some cases it is done by hand labor, in others cases by means of dredgers or steam shovels. This dredger removes the soil resting upon the phosphate, which is then gathered by means of pick and shovel. The rivers in the region contain large quantities of phosphates, and this is obtained in some cases by dredging and in others by means of centrifugal pumps.

By whatever method the phosphate is mined it comes mixed with extraneous matter, as clay, sand and stones, which latter have to be removed. The stones are removed by hand-picking and the clay and sand by washing. One good method of washing consists in conveying the rock through a long semi-circular trough inclining upwards, by means of a spiral conveyor. As the rock goes up it is washed by a stream of water coming down the trough. After screening to take out the remaining dirt and sand and hand sorting to remove other foreign substances, it must be dried before it is ready for market. This is done in various ways, a favorite one where fuel is cheap is to prepare a pile of wood with the phosphate rock on top. This is fired, when the whole of the moisture is driven off. This drying is necessary since wet stone is exceedingly difficult to grind.

Vast quantities of phosphate have been discovered in the islands of the Pacific, as for instance, Laysan, Ocean, Christmas, etc. These deposits are probably all of bird origin, the original material being the excrement and bodies of birds which inhabit the islands. The surface of the deposits is often brown, powdery, containing a small amount of ammonia, while the deposit beneath is hard and rock-like, containing little or no ammonia, but a higher percentage of phosphate.

The bones of animals also contain a large quantity of phosphate, and they are today used in almost all parts of the world for fertilizing purposes. The packing houses save all the bones, the greater portion of which are ground into a fine flour or meal; in which shape, either alone, or in conjunction with other substances, they are applied to the soil.

In the year 1840, Liebig, a celebrated scientist, suggested the addition of sulphuric acid to bones in order to render the phosphoric acid soluble, believing that this would render it more available to the plant. This suggestion was adopted by J. B. Lawes of London, and he began the manufacture and sale of artificial fertilizers, using this dissolved bone as the basis. Soon afterwards Cambridge coprolites, which is a low grade phosphate, was similarly treated, and from this small beginning the immense trade in superphosphates has resulted. At the present time very little phosphates are applied as a fertilizer without this preliminary treatment with sulphuric acid to render the phosphoric acid soluble.

b—Potashes.

Formerly the chief source of potash salts was wood ashes, but the potash mines of Germany now supply most of the potash salts used both in the arts and in fertilization. In 1857 the Prussian government bored near some salt springs in an attempt to find deposits of common or table salt. A deposit was struck in the vicinity of Stassfurt, at a depth of 1,080 feet, and for some time thereafter the mine was worked solely for the salt.

In getting to this salt they went through deposits of potash and magnesia salts for which they had no use, and these were thrown out near the mouth of the mine. These were the byproducts, so to speak. About 1860 the great value of potash in agriculture became known through the researches of Liebig, and a factory was established at Stassfurt at once for the purpose of refining or purifying th potash salts. From this has grown one of the great industries of the world, and today the common salt is the by-product. The potash strata lies from 1,200 to 2,500 feet below the surface and is of very great thickness, and as a large stretch of country is underlaid with these deposits the supply of potash is well nigh inexhaustible. This country was at one time an inland basin below the sea level, with probably a channel leading from the sea which allowed access to the sea water at high tide. As this sea.water containing salts of sodium, potash, magnesium, lime, etc., evaporated the salts were deposited somewhat in layers, depending on their respective solubility.

Table salt ,being the least soluble under the conditions, was deposited first, hence we find it at the bottom of the mine; after that sulphates of lime, potash and magnesia, and finally chlorides of magnesia and potash, crystallized out in layers more or less clearly defined. The process of manufacture consists in separating the other salts from those of potash, and the laws of crystalization and solubility suggested the best way of doing this. In other words, if two salts of different solubility are desired to be separated from each other, the solution of the two are evaporated and the less soluble allowed to crystalize, when the remaining solution is evaporated and the other salt in turn crystallizes. Potash is sold to the manufacturer of fertilizers either as a sulphate or a muriate, often mixed with salts of magnesia. The muriate is somewhat cheaper, but in Hawaii the sulphate is generally preferred, notwithstanding its higher price.

The consumption of potash salts, both for industrial and manurial purposes is considerably more than 3,000,000 tons per year. The German government has united the various large mines into one syndicate and now controls both the output and the price.

Up to the present time no other deposits of potash salts of any value have been discovered, but there is no reason to believe that none exist. Conditions like to those at Stassfurt may have produced similar deposits in other parts of the world, but of this we have no tangible evidence.

c—Lime.

While lime is used as a fertilizer in some cases, it is probably never often used to improve the physical properties of the soil. It is an element rarely considered in the manufacture of fertilizers inasmuch as the phosphates carry a sufficient quantity for ordinary field crops. The coral sand which may be had almost for the asking and which is found in vast quantities on our sea shore, is one of the best forms of lime to apply to Hawaiian soils.

d—Nitrogen.

This is the most important element to the Hawaiian planters for the reason that most of our soils respond readily to some form of nitrogenous material, and because it is by far the most expensive ingredient of fertilizers.

Moreover, sugar cane requires large quantities of available nitrogen for its best development. According to the reports of the Hawaiian Experiment Station, White Bamboo cane removes 20.2 pounds of nitrogen per ton of sugar, or say, 100 pounds per acre for a crop of five tons of sugar. Much of the phosphoric acid, lime and potash taken up by the cane is returned to the soil in the ashes, and a greater part remains on the field in the tops and leaves. As these substances are not volatile they are not lost by burning the trash. On the other hand, whatever nitrogen is taken up in the tops and leaves is a total loss, since it is volatilized when these substances are burned.

From my own experience I should say that more than twice as much money is spent in Hawaii for nitrogen in its various combinations than for all other fertilizing elements combined. Nitrogen for manurial purposes is derived from the following sources:

(1)—*Nitrate of Soda.*

Like potash, nitrate of soda, or saltpeter, comes from but one locality, namely, the dry western slopes of the South American Andes, in Chili, Peru and Bolivia. Below the surface of the soil, from three to ten feet, is found the crude nitrate, or nitrate mixed with soil. The thickness of this layer is as much as ten feet, the average probably being three. These immense deposits were formed by the decay and nitrification of large quantities of organic matter, and this being a rainless district, the resulting nitrate which is very soluble in water, accumulated in large quantities. No natural deposits either of nitrates or any other material high in nitrogen are found in districts of considerable rainfall, nor can they be formed since rain water washes them away.

This is one, and the chief reason, why the guano deposits of the Pacific islands, Christmas, Ocean, Laysan, etc., are composed chiefly of phosphates and but little nitrogen. On the other hand the guano deposits of Peru and other countries of Western South America, where there is little rainfall, are highly nitrogenous and very valuable.

Indeed, many years ago the Peruvian guanos were exported in large quantities to England and was almost the only fertilizer of consequence used. The export from the islands was so heavy as almost to exhaust the deposits, and the guanos became deservedly popular with the farmers.

(2)—*Sulphate of Ammonia.*

This is another important nitrogenous compound, and the most expensive of raw materials used in fertilizing. It is a by-product in the manufacture of coal gas, and comes chiefly from England, though small quantities are made in the United States and Germany. It results from destructive distillation of coal, the nitrogen originally stored in the wood from which the coal is derived being converted into sulphate of ammonia. Other sources of ammonia are blood, tankage, which is a waste product in the slaughterhouses, dried fish, etc.

Some fear has been expressed among scientific men that the supply of nitrogen compounds would eventually become exhausted, that the earth would become impoverished from cropping and cease to yield harvests since there would be no nitrogen with which to manure; and that the world would come to its end through starvation. Thus, the supply of sulphate of ammonia is a limited one; at the present rate of increased consumption of nitrates the Chili beds will become exhausted within thirty years; and the nitrogen compounds of the soil are being used up through cropping. Again, there is a great loss of nitrogen through the sewage, which goes to waste in the rivers. But this danger of starvation is a remote one, for already nitrogen is being gathered from that immense storehouse, the atmosphere, of which it forms the chief portion, by means of power plants at Niagara Falls, and other water falls in Norway. At present the process is expensive even with cheap power, but there is every reason for believing that all the difficulties of the problem will be overcome long before other supplies of nitrogen have become exhausted.

Even if this should fail, nature has placed another safeguard in the way of utter depletion of nitrogen. It was observed in very early times that leguminous crops enriched the soil, though in what way was not known, and they were thereafter used in a well directed crop-rotation. In what way the soil was enriched or rejuvenated was not known until modern science attacked the problem. It was found that certain bacteria working in the nodules of the roots of leguminous crops, abstract nitrogen from the atmosphere and add it in an organic combination to the roots and stems of the plants. After the plants die and decay this nitrogen becomes available to other crops grown on the same soil, hence it is practicable to grow one kind of crop only for the nitrogen which it will take from the atmosphere and supply to succeeding crops. While rotation of crops would be expensive in Hawaii because of the great value of the land and of the sugar crop it would be practiced were not nitrogen in a commercial form so readily available.

(3)—*Hawaiian Methods of Fertilizing.*

I trust that I can give you an adequate idea of the difficulties encountered in attempting to find the right kind of fertilizers for the plantations.

Take the two factors, which are the leading ones in agriculture, namely, climate and soil, and see how different they are on the various plantations. The rainfall in Hilo may reach 200 inches in a single year, Hamakua is subject to drouths and occasional floods, while many plantations on all of the islands, with the exception of Hawaii, depend almost exclusively on irrigation. The rainfall then varies between the wide limits of a few inches to say twelve or fifteen feet per year.

Again the soils of no two plantations are exactly alike, and, indeed, on the same plantation you find several types. These soils differ not only in the total content of plant food as shown by the chemical analysis, but also in the amount of *available plant food.*

As an example of the difference in chemical analysis of two different fields on the same plantation, we will give a single example

	Field 1.	Field 2.
Lime	1.53%	1.46%
Phosphoric acid	.13%	.33%
Potash	1.03%	2.10%

It was long ago recognized that the total plant food found in the soil does not give absolutely reliable data as to the value of the soil, nor for the recommendation for fertilizers. Hence many efforts have been made by chemists to perfect a method of determining the available plant food in soils. The efforts have looked toward imitating nature as far as possible, in other words, to use a solvent for the soil that approaches the action of crops on the soil constituents. A few years ago the Hawaiian Experiment Station devised a method, using aspartic acid as a soil solvent, and this has given fairly good results as to lime and potash.

We will now give the *available* plant food of the same two soils noted above, using aspartic acid as the solvent:

	Field 1.	Field 2.
Lime	.096 %	.215 %
Phosphoric acid	.0007%	.0001%
Potash	.034 %	.047 %

Although the two fields contain approximately the same total amount of lime, No. 2 contains double the amount of lime that No. 1 contains. Again, No. 2, is fairly rich in phosphoric acid, but only a mere trace is dissolved by aspartic acid.

Finally, while No. 2 contains twice as much potash as No. 1, the *available* potash is but 40% greater.

Evidently any system of fertilization that does not take into account these radical differences in the very nature of the soil is wrong.

There is another serious difficulty in the way. We have soils ranging all the way from a few inches to many feet in depth. Although the first soil should show a good analysis, a crop would starve without artificial assistance, while the second soil might show a very poor analysis and yet yield good crops.

It is thus seen that neither the chemical analysis of the soil, nor the climate, nor the rainfall, nor any other single factor can give reliable data for fertilization, but all of the factors together must be considered.

Nitrate of soda, one of the materials extensively used as a fertilizer, is not only soluble in water, but it is not fixed or held by the soil. It goes wherever the water goes. Hence the danger of applying it to thin soils where there is a great rainfall. The first large rain would wash it out. Nitrate of soda is a stimulant and is used on most irrigated plantations, especially where the soil is rich and retentive of moisture. In many cases it is dissolved in the water of irrigation and allowed to go into the cane rows with the water. This has the advantage of being cheap as to labor, as it can be applied more frequently and in smaller doses than is the case where it is applied by hand. There is always the danger, of course, that part of it may be lost before the water reaches the furrow and by the water passing down through the subsoil and out into the drainage. Undoubtedly a great deal is lost in this way, but what remains behind is of great value to the cane. Of the other fertilizer ingredients, the potash salts, the superphosphates and sulphate of ammonia are soluble in water, but they are not subject to the great waste from water as is the case with the nitrates. It has long been known that potash, phosphoric acid and ammonia are fixed and held by the soils, but to an extent dependent upon the quality of the soil. A few years ago the writer made a few experiments to determine the extent to which they are held by our soils, and under the conditions of an irrigated plantation.

The soil experimented with was a red soil from the Honolulu plantation which is a good type of the red soils found throughout at least three of the islands. This soil was placed in tubs, the fertilizer applied on the surface and irrigated, the drainage water being preserved and analyzed.

The following table gives the results:

Fixation of phosphoric acid, ammonia and potash:

Depth of Soils. Inches.	Phosphoric Acid Retained. per cent.	Retained. per cent.	Ammonia Retained. per cent.
6	99.43	99.84	98.55
1	53.35	50.21	69.19

It was found that practically one-half of the phosphoric acid and ammonia, and 69% of the potash from sulphate of potash, is fixed and held within the first inch of soil, and 99%, or practically the whole, is held within the first six inches of soil. But these elements are gradually dissolved and carried further down by repeated heavy rainfalls or heavy irrigations. "Were the soluble fertilizer ingredients not fixed at once the loss would be very great; but the experiments show that even under heavy washings they are fixed very rapidly. But the solubility of these substances in water after the first irrigation, though slight, emphasizes the importance of keeping the irrigation well under control. The nitrogen of sulphate of ammonia is gradually changed to nitrate, and most of that which the plant has not assimilated is washed away by the first irrigation or heavy rainfall. The phosphoric acid is more firmly bound, and the loss of this substance is very slight. Under the conditions of the tests, 19% of potash applied as sulphate was washed below six inches by eight irrigations.

We thus see that heavy and repeated irrigations wash out the available ammonia and potash; and this will partially account for the fact that very often the effects of a fertilizer, especially of a nitrogenous fertilizer, are not lasting."

(See J. Am. Chem. Soc., Jan., 1903, p. 50.)

Since the establishment of the Hawaiian Experiment Station there has been a great change in the kinds of fertilizers used. Formerly bone meal and other slaughter-house refuse formed the basis of a low grade, insoluble, and slow-acting fertilizer. Both the potash and ammonia content was low, the phosphoric acid high. Now the reverse is the case, the phosphoric acid is low and the ammonia and potash high. The reason of this will be seen by examining the amount of the several plant food ingredients removed by a ten ton crop of sugar, where the variety of cane known as Rose Bamboo was grown, as given in a bulletin of the Experiment Station for 1900.

Elements removed from one acre of soil by a ten ton sugar crop—Rose Bamboo:

	Pounds.
Phosphoric acid	136
Potash	1,142
Nitrogen	405

Application of Fertilizers.

In the rainy districts organic fertilizers, such as bone meal, tankage or fish guano is applied in the furrow and mixed with the soil before planting. This is followed, after the cane is up two or three feet high, by a high grade fertilizer containing a large percentage of ammonia and potash. On some plantations a high grade fertilizer is applied with the seed cane, but on the irrigated plantations the fertilizer is not applied until the cane is growing. Generally two or more applications of a high grade fertilizer are made at intervals, and is usually scattered along the surface of the row, to be followed by irrigation. As the ingredients are water-soluble, they need not be covered with soil for the water dissolves them and carries them down.

Nitrate of soda is applied in one or more doses, and is either thrown into the ditch carrying the irrigation water to the field, or by hand in the furrow, but *after* irrigation.

Present Problems.

One of the greatest needs of the plantations is to devise a method by which water can be equally distributed along the whole course of the furrow without allowing any waste into the subsoil. This would be a great saving in water, and also in fertilizers, for none of the latter would be washed away. A very simple illustration will show you conclusively that much of the water used in irrigation is going to waste through the drainage. The danger point of salt in sugar soils is probably about .2%, or say, 15,200 pounds of salt to the depth of two feet; should salt accumulate beyond this point the cane would be seriously affected. Now water containing 55 to 60 grains of salt per gallon, which is considered quite safe for irrigating purposes, would add to the soil in the neighborhood of 40,000 pounds salt per year, or far more than is necessary to ruin the land. I have made a thorough test of this question and find that salt is not accumulating to any considerable extent, hence it is being washed out in the drainage. But by the same token, fertilizers are also washed away.

Again, the fertilizer value of the molasses from the Hawaiian crop is approximately one-half million dollars. Any scheme for disposing of the molasses should take this into account and save this large sum. In some cases the molasses is burned for fuel purposes, but much of the valuable potash is either volatilized by the high heat of the furnace, or fused into a glass-like clinker that is of no service. Where the molasses is burned a method should be devised whereby this can take place at a low temperature—at a temperature where the potash will neither fuse nor volatilize.

You must pardon me for presenting this question from the agricultural and chemical standpoints, rather than from the engineering, for the engineering problems are in mining and preparing the various raw materials for market; when these materials reach Hawaii, the interest centers in the soil to which they are to be applied, and the crop that is to be grown.

MILL SETTINGS AND MILLING.

Addenda to paper on Mill Settings and Milling, by A. W. Keech, in June Planters' Monthly. This addenda and criticisms set out herewith was read before the Honolulu Engineering Association at its June (1906) meeting:

Honomu, May 28, 1906.

There are some parts which were omitted from my former paper and some of a nature that may make the discussion easier. I make this communication to complete my assertions and bring in the additional matter to be considered as part of the original read at former meeting:

LOADING HYDRAULICS.

The practice observed is quite uniform at the various mills. We are carrying here the following weights::

37½ plates=First Mill.
38½ plates=Second Mill.
41 plates=Third Mill.

The maker's rating is 8.25 tons per plate for 10″ jack (our case), which gives 309.37, 317.62 and 338.25 tons respectively on a 32″x60″ nine roll mill. It is my opinion that 42 plates is a limit for the last mill in our case, with the other mills loaded up to near that number. I am inclined to think that all the mills should be loaded nearly alike from first to last, so long as the feed will work. I wish to observe here that the danger of breaking rolls lies probably much in queer settings of rolls and returner bars, and most in that sticking of jacks of hydraulic gear when there happens some unusual variation in the feed itself; or foreign body by accident in the feed. We had come, in with the feed, quite a large piece of cast iron broken oq from conveyor side; its presence was at once shown by the hydraulic spindles going up into the air; it did no noticeable damage, but any refusal on the part of the hydraulic gear would have thrown an enormous strain on the mill, with probably a break.

Referring again to the proper working of this gear: If in good working order the maximum load may be carried with no danger and with advantage, as the object is to obtain pressure. I am quite sure that continuous yielding pressure above what is usually carried would be far less dangerous than a momentary jam with lighter load.

I can see no reason for very much lighter loads on first and second mills if their grooving is in good condition. The mills are alike in strength to resist strains, so the drier the trash emerges the better for the maceration liquid used. In our case it is second mud press liquor on second mill, and water on last mill. It is obvious that the total load on top roll should be in proportion to size of roll, not only its *length* being considered, but also its *diameter,* as there is more area per unit of length subject to squeeze in a 34″ diameter roll than in a 32″ diameter roll. Of course, if the hydraulic gear is not in best working order loads should be decreased till the gear "floats" and the resultant loss charged to *bad* repair. Extraction is the *object,* and the efficiency depends on a continual application of as great a pressure as practicable, the application of the pressure *not being interrupted though ever so slightly* by the meshing of pinions or movement of jacks. It is natural for the most careful to overlook the importance of *small* matters in *slow* moving, *heavily* loaded machinery.

Confirming my assertions in regard to the meshing of pinion teeth of close set mills, I will say that since writing the original paper read at the last meeting, we found our last mill falling off in efficiency at the beginning of a week's run. No other cause was apparent except the deeper meshing after the usual Sunday "tuning up." It is not much of a closing, only to make up for any wear or backing in the previous week. There occurred a day stoppage in the week following; the pion casing of the third mill was removed and the teeth overhauled for some bottoming and other inequalities: this was followed at once by a marked improvement in extraction. I can assure you that *any unevenness* in the motion of mills has its effect on their efficiency, more noticeable in the close set ones and greatest when the fiber content is less, so that the blanket is thinner and rolls close, allowing the teeth to work at their worst contacts. I found by gauge that the thickness of blanket between top and discharge rolls did not exceed 1-16 of an inch with soft cane and rose to 1-8 of an inch with the harder variety, the same quantity of feed obtaining in both cases. It will be found a source of satisfaction to watch the openings from gauge. I am fully convinced that the variety of cane (hard or soft), and varying feed conditions have not the influence attributed to them, provided all the conditions mentioned are favorable. This is from my experience in the matter. I must again mention Mr. H. D. Deveride, our sugar boiler and chemist; in investigating these matters I have dealt with *causes* and he has kept me informed of the *effects;* his painstaking methods and instinctive detection of error make his results accurate and reliable. Both of us are agreed that there is nothing but harm in any method of "jockeying" for results.

Yours truly,

ALVIN W. KEECH,

Chief Engineer, U. S. Marine License Unlimited.

Criticism by W. A. Ramsay of Catton, Neill & Co., on paper on Mill Settings and Milling by A. W. Keech, Chief Engineer Honomu Sugar Co.:

In accordance with the desire to initiate a discussion expressed by the writer of the paper on "Mill Settings and Milling," read at the May meeting of this association, I propose to lay before you the results of my observations and experience which, I must confess, lead me to entertain grave doubts regarding the soundness of the writer's conclusions and the feasibility of his theories. I listened to the paper with interest and found it very instructive, and believe that a discussion of this important subject would be beneficial to all who are interested in, or in any way connected with sugar mill work.

All that he says about "the top brasses being shoved against the side of the cheek jaw" is no doubt true, but, if the mill is handled with any degree of care, there should be no serious trouble from this cause. That is one of the functions for which the cheek is designed. The top brasses usually have oil grooves cut on the outside at the flanges in order to convey oil to the flat surfaces between the brasses and cheek jaws. If oil is occasionally placed in these grooves, say three times a week, I can see no reason why this "shoving" should cause enough friction to affect the working of a mill, especially when the top roll is being moved up and down by a weight or pressure of from 300 to 450 tons. This small friction on the sides of the brasses sinks into insignificance when we consider the enormous pressures we are dealing with.

I am still of the opinion that no hard and fast rule can be made by which mills can be set; and yet I maintain that it is far from being "beyond law and order." But I believe the only "law and order" necessary will be obtained by the exercise of sound common sense, practical experience and keen observation. If conditions are as they should be in every well-regulated factory, this work will be in charge of a man who has had experience in such work, and also knows when his mill is doing all it should do. True, Mr. Keech's rule would make it "a system and not the arbitrary whim of the 'boss.'" This is a point in its favor, but it does not follow that it will always give the best results. "It gives a standard which may be followed," he says, "or a standard from which to vary." To me a standard which permits of variations is no standard at all. The amount of variation in different mills depends on local conditions and, in most cases, if the variations met the original standard they would fail to recognize the slightest relationship.

Some of these variations I might mention in passing. If, after starting a new mill with his setting or standard, one should learn, after a few months' grinding, that the front roll of the first mill is an exceptionally hard one, and does not pit as some of the medium-hard rolls do, and will not take the cane as it should, it will be necessary to open the mill in order to get the amount of cane through that would be possible had the roll been softer, you will need more cane to do your best work with the back roll of the same mill. If the returner bar is of steel, and the lip turns up in places, or if it is of cast iron and refuses to scrape the front roll for some unknown reason—as it sometimes will—it naturally follows that the roll will not draw the feed into the mill as it ought to do. There is nothing to be done but vary its position until you can take the mill apart and put the returner bar in good working order. Suppose the scraper of the top roll is not scraping well and you just can't make it do so, again the only remedy is to open the mill until the scraper can be repaired. If the scraper of the back discharge roll goes lame or does not do just as good work as it should do for some cause which you cannot remedy immediately, you must change your setting and do it quickly if your front roll is taking the feed well, because the front roll is feeding its full supply of cane, while the back roll is unable to take it away from the returner bar as fast as it accumulates. A mill is just like an animal in this respect that, if it has over-eaten, it soon becomes deranged internally. The returner bar must either stand the enormous strain and grunt and groan in so doing, or be bent backward from the front roll or downward from the top roll, or both. This often happens as every sugar mill engineer knows. Many other circumstances tend to change conditions and call for variations from any possible rule. The nature of the cane itself has much to do with determining the way in which the mills will work with a certain setting. Most engineers will agree that one can grind Lahaina cane with a smaller opening than that necessary for Yellow Caledonia.

The following are a few of the conditions which I have concluded to be necessary in order to obtain the best results: The first mill, in order to do its best work, should always be full of cane or just on the verge of choking, and the back roll should be adjusted so that it is in exactly the same condition. This is a very hard thing to determine and yet it is so important that I don't think we can rely on any set rule, but must simply leave it to the good judgment of the man who is handling the plant. He usually knows the little weaknesses of the various parts and can make the right allowance for them. On a new, up-to-date mill I handled for some years, I kept the back roll adjusted so that, if I turned the adjusting screws of the back roll a sixth of a turn farther into the mill, it would immediately start to groan slightly. This, I considered, an indication that the mill was just on the verge of having too much cane fed into it for the opening of the back roll. I simply kept it within a sixth of a turn of that place, or just short of the "choking point." I kept all the rolls adjusted throughout all the mills so that they were as nearly at the "choking point" as possible and yet not sufficiently close to give any trouble by doing so. This arrangement ensures the balancing of the pressure between the two bottom rolls as nearly as possible, because the space between the front and top rolls is filled with cane to the limit and so is the space between the back and top rolls. Thus the load is almost balanced. To illustrate how near the mills in question were kept filled to the limit with cane, I might mention that, if the percentage of maceration-water was increased from 20% to 30%, it immediately became necessary to open the mills slightly because the trash seemed to swell sufficiently, after absorbing the extra water, to cause trouble by piling up in front of the mill until either less water was used or the mill readjusted. I would not advocate keeping the mills as close as this all the time, but, I think, in order to do the best work, something approximating this condition should be reached.

The setting of this mill was: First mill, 13/16″ and 7/16″; second mill, 7/32″ and 1/64″; third mill, 5/16″ and O, or "iron to iron." This setting will, I expect, be criticised by some, but I simply mention it to show how one can vary and still do good work. The first mill, 13/16″ and 7/16″, is a variation from Mr. Keech's rule but, should one close the back roll of this mill, he would immediately hear noises which would convince him that something was wrong. On investigation he would find that the front roll was over-feeding the back roll. The second mill, with

7/32" and a drop to 1/64", always did good work. Now, according to Mr. Keech's formula, we would require 13/32" for the second mill feed roll instead of 7/32",—almost double the opening. Not the difference. It would appear therefore that, if anything even approximating Mr. Keech's rule had been adopted, say 13/32", the bagasse would not have been properly crushed, *seeing that it undoubtedly did go through the 7/32" opening without any trouble.* Another peculiar feature about the setting in question is that the third mill has openings of 5/6" and O, which is 3/32" in excess of the second mill. By Mr. Keech's rule this opening should be slightly over ⅛". With an opening of ⅛" it would have been impossible to get the bagasse through the mill. It would choke and pile up in front of the mill and would soon break the intermediate carrier slats. This apparently excessive opening is explained by the fact that the greatest quantity of maceration-water in this particular case was applied after the cane left the second mill.

Mr. Keech is probably on the right road when he proposes a method whereby one can see the openings of the mill when it is in operation. If the top roll of a mill, having 400 tons hydraulic pressure, and with an opening of 5/16" and O, should rise 5/16", the openings between the front and top roll and back and top roll would be changed to 5/8" and 5/16" respectively, a ratio of two to one instead of 5/16" to O as formerly. If the pressure were cut down to 300 tons, or increased to 450 tons, it would naturally follow that the roll would rise or fall directly in proportion to decrease or increase of pressure. This fact gives us another good reason for varying from any set rule as local conditions sometimes necessitate during a season's grinding. For instance, the engineer may have to contend with loose shafts, hot bearings, etc., which force him to lower the pressure.

I have yet to be convinced that any set rule can be framed whereby mills can be set except it be a rule from which to vary, and, if one adds *that,* it can be made to mean almost anything, depending on what the man who makes use of the rule considers variations. It seems to me to be analagous to adjusting a ship's rudder in Honolulu so that it would guide her to San Francisco. Local conditions are sure to vary in different places and, so long as they do vary, the mill settings must also vary to fit the changing conditions.

I think that an improvement to Mr. Keech's arrangement and setting of knives would be to attach two knives to the same hub at opposite sides. This would help to balance the shaft and enable one to run it at a higher speed. Of course this calls for a special hub casting, arranged so that the knives travel in different paths. My experience is that driving these knives with a separate engine proves more satisfactory than any arrangement for driving them from the main engine as is done in some mills. I have had good results with knives set 2¼ inches apart and running 400 R. P. M., driven with an 8-inch belt. At this speed the belt seldom runs off and the knives never stick when they are called upon to cut up extra large bundles of cane. They will go right through it and the cane is leveled on the carrier surprisingly well. To do this properly, one should have a carrier made of ⅛" steel plates, with each plate overlapping the one in front of it by one inch, so as to prevent small pieces from falling through, as is the case in a wooden carrier with openings between the slats.

Criticism by J. N. S. Williams, Chief Engineer Hawaiian Commercial and Sugar Co., on paper on Mill Settings and Milling by A. W. Keech, Chief Engineer Honomu Sugar Co.:

To the Chairman Honolulu Engineering Association, Honolulu:

The paper on the subject of mill settings and milling by Mr. A. W. Keech, is one that is of great interest to all engaged in the sugar industry in these Islands; and the attempt of Mr. Keech to reduce to rule and law an operation common to all types of crushing mills now employed in this country, is admirable in its conception and presentation.

But before this proposition can be accepted as a solution of the problem, "*how to set a cane crushing mill by rule to give the best results,*" it must stand the test of destructive criticism, and a critic of this class is, in the euphomious language of the day, termed a "Knocker," and is generally credited with a small mind and a mean disposition. Such is life!

In the first place before going into the merits of the formula for finding roll openings proposed by Mr. Keech, it will be well to point out, that the load on the top roll of a three-roll mill of modern type is that produced by the combined action of the hydraulic rams applied to each journal of the top roll shaft. Mr. Keech does not state in this communication just what work he is doing with this adjustment; he, however, says that he does not change the settings on account of variety of cane. From the weekly reports issued by the Hawaiian Sugar Planters' Association we find that the average work done at Honomu by the milling plant is, taking an average of fifteen weeks' work, as follows:

Cane ground per hour	17.6 tons
Moisture in the bagasse	43.31%
Average dilution of mixed juice	13.57%

As the mill rolls are five feet long these figures show that $\frac{17.6}{5}=3.5$ tons of cane are put through the mill per foot of width per hour, the dryness of the bagasse is very creditable, but the dilution is small.

This mill is not being worked to its full capacity, which is at least five tons of cane per foot of width of roll per hour and still get good work.

Operating the mill so much below its normal capacity naturally makes for good and regular crushing, and the small quantity of cane ground ensures the quality of the cane as to hardness, fibre content, etc., being fairly regular; and while this load can be, and generally is, equally divided over the front and back rollers of the first mill of a six-roll, nine-roll or twelve-roll crushing plant; it is not, and cannot be, equally divided over the front and back rollers of any of the other three-roller mills in the tram.

This must be so apparent to all having experience with crushing mills that argument seems to be unnecessary, but as a fact the formula to be considered supplies any argument that may be required to prove this.

On the general proposition that we are not surveyors laying out a scheme of mill openings by means of latitudes and departures, we will neglect the trigonometrical terms in the formula and get down to plain figures. According to actual practice at Honomu, which place is fitted with a nine-roller crushing plant, rollers 30″ diameter x60″ long, we find that the setting there is as follows:

Feed Rolls	1st mill opening	$=A=\frac{3}{4}$	inch
	2d " "	$=B=\frac{A}{2}=\frac{3}{8}$	"
	3rd " "	$=C=\frac{B}{3}=\frac{1}{8}$	"
Discharge Rolls	1st mill opening	$=E=\frac{A}{3}=\frac{1}{4}$	inch
	2d " "	$=F=\frac{E}{4}=\frac{1}{16}$	"
	3rd " "	$=G=\frac{F}{27}=\frac{1}{432}$	"

The conditions under which mills operate when they are forced to their full capacity are very different, and rules which may apply in the one case are almost sure not to apply in the other. To illustrate the foregoing, the following mill setting taken from actual work, compared with a setting for the same mill by the Keech method is given.

The mill is a twelve-roller plant, 34″x78″, operating upon irrigated cane of about 20 months' growth:

Feed Rolls	1st mill opening	$1\frac{1}{4}$ inch	$A=$ $1\frac{1}{4}$ in. $=A$
	2d " "	$\frac{7}{8}$ "	$\frac{A}{2}=$ $\frac{5}{8}$ " $=B$
	3rd " "	$\frac{1}{2}$ "	$\frac{B}{3}=$ $\frac{7}{32}$ " $=C$
	4th " "	$\frac{1}{2}$ "	$\frac{C}{4}=$ $\frac{2}{32}$ "
Discharge Rolls	1st mill opening	$\frac{1}{4}$ inch	$\frac{A}{3}$ $\frac{7}{16}$ " $=E$
	2d " "	$\frac{1}{8}$ "	$\frac{E}{4}$ $\frac{7}{64}$ " $=F$
	3rd " "	$\frac{1}{32}$ "	$\frac{F}{27}$ iron iron $=G$
	4th " "	iron to iron	$\frac{G}{256}$ iron-iron

This mill grinds from 32 to 35 tons of cane per hour, equivalent to 5 tons of cane per foot of width of roll per hour, dilution is from 20%-24%, and moisture in bagasse averages about 44%. An examination of the figures will show at once where the Keech setting for that twelve-roller mill would fail; it would be impossible for the third mill with a feed opening of 7/32" to take all the bagasse coming over from the second mill, and as the thickness of the blanket of bagasse leaving the third mill is approximately the same as that leaving the second mill, it is of course apparent that the fourth mill, with a feed opening of 2/32", would refuse to negotiate.

The proposition to establish a rule for mill settings by fixing arbitrary feed and discharge openings for the first mill, and proportionately reducing these opening through the train of rollers until a discharge opening of no magnitude is reached, will not bear investigation, for the reason that the solids in the cane leaving the last mill have bulk and must pass the last pair of rolls.

This bulk varies constantly with the different qualities of cane handled, and the differing amounts of water of maceration added to the bagasse between the mills during the crushing. It is probable that with a sufficient number of experimentally proved facts, a rule for mill settings could be evolved, but the number of variables in the formula would be so great, that it would become unwieldly, and the exact and scientific rule would be laid aside in favor of the inexact, but workable "rule of thumb."

The following is a list of some of the variables that would require consideration in the production of a formula for mill settings:

Cane—High land or low land; irrigated or non-irrigated; rattoons or plant; long growth or short growth; green, ripe or over-ripe; hard or soft; Lahaina or Rose Bamboo; diseased or sound; high or low in fibre, etc.

Mills—New or old; heavy or light in construction; whether fitted with crushers and knives or not; rollers newly grooved or not; iron in the rollers soft or hard; engine plenty of power or only just enough; speed of rolls slow or fast, etc.

Maceration—The quantity of water applied, and where, etc.

When to the above is added the personal equations of those in charge of such work, optimistic or conservative, as the case may be, a combination is obtained that would defy the mathematical powers of a Newton to solve so that ordinary mortals could use the results.

J. N. S. WILLIAMS.

Puunene, Maui, June 4th, 1906.

Remarks by Mr. Kopke before the Honolulu Engineering Association at its June 1906, meeting, after answers by Mr. J. N. S. Williams and Mr. Ramsay to Mr. Keech's original paper on Mill Setting had been read:

Mr. Chairman and Gentlemen:

I would like to offer a few remarks on this subject, though nearly all the points I have in mind have been touched upon by Mr. Williams' and Mr. Ramsay's papers in answer to Mr. Keech's communication on Mill Setting.

In looking over Mr. Keech's paper I was surprised to find that he had left out the factor of relative speed, that may exist, between the different mills.

The circumferential speed of the rollers is certainly a factor which should not be neglected in setting mill rollers, and in fact the extraction of juice out of the sugar cane in the milling process depends upon quite a number of conditions.

The resultant effect of these conditions must be met by the setting of rollers.

The most important conditions are:

1st.—The circumferential speed of the rollers;
2nd.—The angle of approach, which depends upon the diameter of the rollers;
3rd.—The conditions of the surface of the rollers, smooth or rough;
4th.—The trueness of the rollers, concentrically as well as longitudinally;
5th.—The percentage of fibre in the cane, which varies about thirty per cent.;
6th.—The maceration; and
7th.—The setting and condition of the returner bar.

I doubt very much that these, and perhaps other conditions which may exist and cannot be predetermined, will allow us to put up any hard and fast rule by which we can calculate the openings between the rollers and be sure of getting the best results.

To illustrate some of the above mentioned points I would like to state that a year or so ago my attention was drawn to a comparison of the work done by the two mills at Ewa plantation. These two mills are alike in points of construction and size, and work alongside of one another under exactly the same conditions. Nothwithstanding this, one mill did more work and gave a better extraction than the other one.

The cause of this difference was found to be in the difference of the condition of the surfaces of the top rollers in the last (third) mills. One was rough and the other one was smooth, one was made of softer iron than the other one.

The rough, soft iron roller took in the feed evenly, effecting a continuous and even pressure over the blanket of bagasse passing through the mill, while the smooth, hard iron roller did not take in the feed continuously, but would for small periods of time break the continuity of the blanket and allow the juice to become enclosed in the small breaks. The enclosed juice was very much in evidence on the discharge side of the mill, where it, when released from pressure, would squirt out with considerable force. The break in the blanket accounted for the less work done and the loss of juice for poorer extraction.

The setting of these mills by Mr. Keech's rule would have been the same, but in practice they could not be the same in order to obtain the greatest capacity and extraction possible for each individual mill.

Let me give another illustration regarding mill setting which is to show how very small measurements in the closing and opening of the spaces between the rollers will affect the working of the mill:

A 34"x78" three roll mill was found not to press the bagasse sufficiently. The lower back roller was set up by the adjusting screw one-eighth of a turn, moving the roller one twenty-fourth of an inch forward horizontally; this was found to be too much; the roller refused to take the feed. The adjusting screw was turned back one-sixteenth of a turn, leaving the rollers one forty-eighth of an inch moved forward. The roller took the feed and pressed satisfactorily.

While the roller moved forward one forty-eighth of an inch the surfaces of the top and bottom rollers did not approach one another by this much.

I have mentioned this case to show that we really come down to very fine measurements in adjusting mills to get them down to proper work. The knowledge of these figures has but little practical value, though they may be interesting and only can be obtained after the adjustment has taken place.

If I had to start a mill and knew nothing of the material to be milled, I would first set the mills as designed by the maker, then would get the first mill to do "good work," then take the second mill, &c., ("good work" should be determined by the extraction obtained and nothing else). After this I would ask my friend Mr. Keech to lend me his micrometer and find out what I had been doing. If I should find that the setting of the mill coincided with Mr. Keech's rule, I would be surprised. Mr. Keech's rule may suit the conditions existing in Honomu exactly and it may be, as he says, a good thing to start with, but I am convinced that it cannot give the best results under all conditions.

I do not wish you to think for a moment that I belittle Mr. Keech's contributions; he is a man of no mean experience and knowledge, who looks for truth and order as we all do, and he will help us to find it. I look forward to have him thrash out this subject and many more to come. This association ought to thank him for preparing his paper, though it may be most cruelly shot at.

THE LIMING OF SOILS.

THE USE OF LIME FOR IMPROVING SOILS.

The recognition of the agricultural value of certain forms of lime is not new, and it appears probable from the writings of Pliny that liming was practiced by the Romans more than two thousand years ago. In England, Germany, France, and other European countries the application of lime in various forms has been and is still practiced extensively. Dehérain states that certain regions of France have undergone a veritable agricultural transformation, owing to the use of lime and marl. Müntz and Girard assert that more than one-fifth of the area of France is of granitic origin, and that when the soils are supplied with lime and phosphoric acid, which they lack, they undergo a complete transformation. In certain sections of Germany carbonate of lime in the form of marl plays an important part in maintaining the fertility of the soil. According to Wicke, the yields in certain districts of Germany have at times been quadrupled by the employment of marl, and many plants, whose cultivation was previously impossible, could be grown at a profit after the soil was limed. Schultz, of Lupitz, one of the most practical agriculturists of northern Germany, demonstrated the immense value of marl in developing the productiveness of the light soil of that section of Germany. By its use, in connection with abundant potash and phosphoric acid, he met success in growing leguminous plants, which gather from the air large stores of nitrogen, thus making it possible by this addition of plant food and humus to cultivate the light soil at a profit. Haxton, in a prize essay, "On light land and farming," mentions a number of siliceous sandy soils in various parts of England which are greatly benefited by liming, and in speaking of the granite formation in Scotland asserts that "the whole of the granite soils are deficient in lime, and the first step toward their improvement, after being drained, is to apply this substance in a hot or caustic state."

Ruffin is perhaps the most prominent of the earlier writers who called attention to the agricultural use of lime in the United States. As early as 1818, and later, in 1821, articles on the subject were contributed by him to the "American Farmer," and in 1832 appeared the first edition of his well known work on "Calcareous manures." He cites many instances showing the benefit derived from calcium carbonate when applied in the form of marl to his own and other Virginia estates. In certain parts of Pennsylvania and New York lime has long been considered one of the essentials in wheat production. The beneficial effect of liming has been demonstrated in Alabama, Alaska, New Hampshire, Massachusetts, New York, Virginia, Maryland, Pennsylvania, Oregon, Illinois, and other parts of the United States, but, as Roberts states, probably 99 per cent. of the arable soil of the United States has never been limed, and indeed many large areas are not in need of it. The work of the experiment stations, stimulated at the outset by that of Rhode Island, has now shown conclusively that soils which respond profitably to liming, either on account of their acid condition or of a deficiency of lime in other respects, are very widely distributed.

DIRECT MANURIAL ACTION OF LIME.

Authorities seem to agree that lime is necessary to the plant, and if it be wholly lacking in soils, even though an abundance of all the other essential elements is present, the plant cannot develop normally. The plant cannot grow if any one of the essential elements of plant food is lacking. As already stated, lime has been found to be especially deficient in soils derived from granite. It is also often true of soils derived from mica-schist, sandstone, and from certain conglomerates, slates and shales. Fortunately, however, many soils are well provided with lime by nature, and it is seldom or never necessary for those who cultivate them to resort to liming. It would be just as irrational to apply lime where it is not needed as to omit it where it is required, and hence arises the necessity of ascertaining the needs of particular soils in this respect. The method usually resorted to for ascertaining the amount of lime in soils is to treat them with some strong mineral acid (usually hydrochloric) and determine the amount of lime which is thus dissolved. Some writers state that if only one-half of one per cent. is thus shown to be present, immediate resort to liming is desirable; others set the amount higher, and some seem to prefer to have present as much as one per cent. It is possible that a soil may contain considerable quantities of lime thus removable by acid, and yet in actual practice show much benefit from liming. As a matter of fact, soils of limestone origin sometimes show benefit from liming because sufficient carbonate of lime is not present in the soil.

This is due to the continual removal of carbonate of lime by crops and by leaching. Often some carbonate remains, but it is too much inclosed by other materials to be sufficiently active to prevent acidity and to insure the proper changes in the organic matter. The fact that beets of all kinds make a ready response to liming on soils which are deficient in carbonate of lime may be utilized as the basis for a practical and reliable method of testing the lime requirements of the soil. For this purpose lay out two plats of land, each about 12 by

30 feet, manure each of the plats with like amounts of a fertilizer containing potash, phosphoric acid, and nitrogen, and apply lime to one of the plats at the rate of from 1 to 2½ tons per acre (40 pounds per plat would be approximately 2½ tons per acre). A comparison of the growth and yields on the two plats will furnish a safe means of judging whether the soil will respond profitably to applications of lime. If the crop is helped but slightly by liming, most varieties of plants will not be in immediate need of lime. If the crop is greatly helped or is increased several times, it is likely that the soil is too much in need of lime to make complete success with most varieties of plants possible.

CHEMICAL ACTION OF LIME ON SOILS.

Lime is said to take the place of potash in certain chemical compounds which exist in soils, thus liberating the potash and placing it at the disposal of plants. In this particular, gypsum (land plaster or calcium sulphate) is believed to act more energetically than carbonate of lime, air-slaked or water-slaked (hydrated) lime. When soluble phosphates are applied to soils deficient in lime and magnesia the phosphoric acid combines with the iron and alumina of the soil to form compounds which are not readily utilized by plants. If, however, the soil is fairly well supplied with lime and magnesia this transformation is retarded, so that the plant is afforded an opportunity to utilize much of the phosphoric acid before it becomes unassimilable. If a soil containing a certain inert phosphate of iron is heavily limed, it is believed that this phosphate will be changed into a form which the plant can utilize. Lime may therefore not only aid in keeping recent applications of phosphoric acid in assimilable condition for a long time, but it may, if applied in sufficient quantity, help to unlock stores of phosphoric acid, in certain soils, which plants would otherwise be unable to use.

Hilgard has abundantly demonstrated the great value of gypsum (land plaster) in renovating "alkali" soils in the arid dition of the soil the gypsum reacts with it, producing sodium carbonate (black alkali) is the cause of the unproductive condition of the soil the gypsum reacts with its, producing sodium sulphate and carbonate of lime, whereby the alkalinity may be sufficiently reduced to render possible the profitable production of crops. In case protosulphate of iron and certain other poisonous compounds are present in soils, liming so changes them as to render them harmless to plants.

When the remains of plants undergo decay upon soils deficient in carbonates of lime and magnesia, acid or sour humus is liable to be produced, which is supposed to be particularly noxious to most agricultural plants, though apparently not detrimental to the growth of the cranberry, watermelon, rhododendron, azalea, and a few other herbaceous plants, trees, and shrubs. Such conditions are liable to occur even in upland and naturally well-drained soils. Liming is, in all such cases, an effectual and probably the most economical remedy.

PHYSICAL EFFECTS OF LIMING.

Many clay soils when wet by rains are not porous enough to allow the water to pass through them with sufficient rapidity, in consequence of which they become water-logged, and air which is necessary for the healthful development of plant roots within the soil is excluded. In times of drought, also, such soils cake readily, thus becoming more difficult to till and less adapted physically to the growth of plants. Liming is an effective preventive or remedy for all of these unfavorable conditions. Upon certain loamy soils containing considerable clay, liming often renders the surface more friable and less liable to form a crust upon drying. The improvement of drainage brought about by liming is one of the most effective means of preventing surface washing. When heavy rains occur on limed soils the water sinks into the soil instead of rushing over the surface, carrying the fine soil particles with it and thus producing galls and washes.

Soils which are composed of siliceous sands are frequently benefited by being rendered more compact by liming. On such soils pulverized limestone is preferable to ground burnt lime, hydrated lime, or even air-slaked lime, owing to the more powerful action of the latter, and the best material to employ where it is obtainable is a clay marl containing a fair amount of carbonate of lime. The clay, as well as the lime, tends to materially improve the physical condition of the soil. It should also be the aim to increase the amount of organic matter in such soils by the use of muck and stable manures, or by the occasional plowing under of a green crop or of sward.

EFFECT OF LIME ON THE ACTION OF MICROSCOPIC ORGANISMS IN THE SOIL.

Many important changes are produced in the soil by organisms so small that they can only be observed by the aid of the most powerful microscopes. Some of the changes of this character, in which lime plays an important part, are the following:

(1) The change of ammonia and of nitrogen in organic matter, such as blood, meat, fish, tankage, plants, etc., into nitrates, the form in which it is chiefly assimilated by most cultivated plants. This is known as the process of nitrification and is promoted by the presence of lime in soils.

(2) The decomposition of organic matter in muck and other soils. In this process the production of carbonic acid is much accelerated by the use of lime. This carbonic acid in turn so acts upon inert plant food of the soil as to make it more quickly available to plants. The indirect result, therefore, is to help the plant to draw more potash, phosphoric acid, etc., from the soil than would otherwise be possible.

(3) The utilization of atmospheric nitrogen by certain of the leguminous plants (notably the clovers), particularly upon sour soils, is facilitated by the application of lime.

LIMING SOMETIMES INJURIOUS.

Excessive amounts of lime, especially on light soils, may have an injurious action. This is particularly true of freshly slaked lime and of ground limestone upon light sandy soils, which are inclined to be dry and which contain only small amounts of organic matter. It hastens unduly the decomposition of organic matter, and thus renders the soil more open and less retentive of fertilizers and moisture than before. If either ground burned lime or slaked lime must be used upon such soils it should be applied in small amounts and at not too frequent intervals. As stated heretofore, clay marls are much better adapted than other forms of lime for the improvement of such soils. In lieu of such marl either wood ashes or lime, which has been exposed to the action of the air for a long time, is usually preferable to lime which has been recently prepared. Before the advent of "complete" fertilizers it was a common adage that liming "makes rich fathers and poor sons." If lime is used alone it serves to "liberate" potash, nitrogen, and sometimes phosphoric acid, and often the extra drain of increased crops on the soil leaves it finally in a worse condition than at the outset. In other cases the soil reverts after many years to its former state of unproductiveness, without appreciable injury. Continued success with lime can only be assured by the use of other essential manurial substances in connection with it. Few, if any, cases are on record where soils originally in need of lime have failed to continue to give good results from liming when care has been taken to maintain a proper supply of the other essential constituents and where lime has been applied in moderate amounts. There are impure limestones which, after burning, yield material that will harden like cement, and which, on this account, may have an injurious action upon the soil. If such limestone is pulverized without burning it is capable of yielding good results.

Dolomitic (magnesian) limestone contains widely varying percentages of magnesia and lime. Such stone, if containing high percentages of magnesia, may sometimes prove objectionable if used exclusively. Should injury arise from the accumulation of an undue amount of magnesia, this can be overcome by an application of ordinary lime. Rather than to use magnesian lime successively upon the same land it would be preferable to replace it frequently with lime containing little or no magnesia. Notwithstanding what has been said, the presence of some magnesia in lime is by no means objectionable, and it may, on certain soils, prove positively beneficial.

PLANTS BENEFITED BY LIMING.

The following are some of the plants which, in experiments on acid soil at the Rhode Island Agricultural Experiment Station, have shown marked benefit from the use of lime: Spinach, lettuce (all kinds), beets (all kinds), okra (gumbo), salsify (vegetable oyster), celery, onion, parsnip, cauliflower, cucumber, eggplant, canteloupe, asparagus, kohl-rabi, cabbage, dandelion, Swedish turnip, pepper, peanut, English or flat turnip, upland cress (pepper grass), martynia, rhubarb, common pea, pumpkin, summer squash (scalloped), golden wax bean, red valentine bean, horticultural pole bean, bush Lima bean, lentil, Hubbard squash, saltbush, hemp, tobacco, sorghum, alfalfa, clover (red, white, crimson, and alsike), barley, emmer, wheat, oats, timothy, Kentucky bluegrass, Canada pea, Cuthbert raspberry, gooseberry, currant (White Dutch), orange, quince, cherry, Burbank Japan plum, American linden, American elm, sweet alyssum, mignonette, nasturtium, balsam, pansy, poppy, and sweet pea. The crops were not only greater in many cases, but they were ready to be marketed much earlier where the soil had been limed. Tobacco not only made a better growth when limed, but the ash was much lighter in color.

So far as concerns potatoes, the total crop is frequently not materially increased by liming, but the percentage of tubers of merchantable size is usually increased if the soil is quite acid, thus adding greatly to the total value of the crop. On account of the fact that liming increases the injury caused by potato "scab" care must be taken to treat the "seed" tubers with corrosive sublimate solution, formalin, or other fungicide* capable of destroying most of the germs of the disease before the tubers are planted. Furthermore, lime should be applied after the removal of the potato crop, except in case of land that has not been previously limed.

PLANTS BUT LITTLE BENEFITTED BY LIMING.

There are many plants which, when supplied with sufficient potash, phosphoric acid, and nitrogen in immediately assimila-

* For method of treatment see U. S. Dept. Agr., Farmers' Bul. 1.

ble combinations, such as nitrate of soda and nitrate of potash, show but little if any benefit from liming even upon quite acid soils. Among these plants are the following: Indian corn, spurry, rye, carrot, chicory, Rhode Island bent, and redtop. Upon a very acid soil some of these plants might show greater benefit from liming provided the nitrogen were supplied in sulphate of ammonia, blood, tankage, fish, cotton-seed meal, plant roots, or other nitrogenous substances, the decomposition and nitrification of which would be hastened by the presence of lime.

PLANTS USUALLY OR FREQUENTLY INJURED BY LIMING.

Among the plants which have shown slight injury from liming under certain conditions and which may, under other circumstances, be helped by it are the following: Cotton, tomato, cowpea, zinnia, phlox (Drummondi), Concord grape, peach, apple, and pear. The plants that have quite persistently shown marked injury from liming are: Lupine, common sorrel, radish, velvet bean, flax, castor bean, blackberry, black-cap raspberry, cranberry, Norway spruce, and American white birch. Extensive European tests have also shown that lupine is injured by liming. Lime, though directly injurious to common sheep sorrel, aids in ridding land of it more by virtue of encouraging other plants than on account of the direct injury which it causes. It is claimed that the chestnut, azalea, and rhododendron are injured by lime, though they have not yet been tested at the Rhode Island Station.

The Rhode Island soil, upon which the tests referred to were made, is what has been termed a "silt loam," in which the water table is usually from 12 to 15 feet below the surface.

INFLUENCE OF LIME UPON SOME PLANT DISEASES.

Potato Scab.—It has been shown that carbonate of lime and such other compounds of lime as are changed into the carbonate by decomposition within the soil all tend to favor the production of potato scab, provided the germs of the disease are already in the soil or are introduced into it on the seed tubers. This seems to be due to the fact that the lime makes the soil alkaline, or to some influence which the combined carbonic acid of the carbonate of lime exerts upon the development of the fungus.

In view of this unfavorable action of lime caution should be observed in liming potato fields in the manner suggested on a previous page.

Club Root.—Many writers seem to agree that liming is capable of lessening materially the injury to turnips, cabbages, etc., caused by the disease known as "finger-and-toe" and "club root." English writers assert that by resort to liming excellent crops of turnips have been produced where without it the crop was a failure, owing to the attacks of the disease.

Other Diseases—The effect of different compounds of lime has been tested, with not entirely conclusive results, on various other diseases, including cranberry and sweet potato diseases, and a root disease of alfalfa *(Rhizoctonia medicaginis)*. Slaked lime was found to be effective in reducing soil rot of sweet potatoes, and quicklime in checking or preventing the root disease of alfalfa.

HOW OFTEN SHOULD LIMING BE PRACTICED?

The frequency with which liming should be practiced depends upon several conditions; for example, upon the character of the soil, the quantity of lime employed in each application, the number of years involved in a rotation, the plants to be grown and their order of succession. Formerly, in England, large quantities of lime were applied at somewhat rare intervals, but there and elsewhere at the present time the preferable practice seems to be to use small amounts and apply it more frequently. As a general rule it may be stated that from half a ton to one and a half tons of lime per acre applied every five to six years is sufficient. There may exist extreme soils requiring either more or less than these amounts. If soils which are quite acid and have not previously been limed are to be seeded, with the intention of allowing them to remain in grass for several years, as much as two or three tons of lime per acre may sometimes be advisable. Only very extreme cases would call for larger applications. If in a rotation covering a considerable number of years two crops especially benefited by lime are introduced at about equidistant intervals of time, it may be advisable to lime twice in the course of the rotation, each time just prior to their introduction. In renovating acid pastures and meadows it is usually preferable to apply a fair amount of lime upon the furrows when they are first plowed, so that this may be thoroughly mixed with the soil by subsequent plowing and harrowing, and just prior to seeding to grass make another generous application. By such treatment, provided the other essential fertilizing ingredients are employed, a good stand of clover, Kentucky blue-grass, timothy, and other grasses may be obtained where in many instances they were formerly partial or total failures and where only redtop, Rhode Island bent, and grasses having similar soil adaptability could be grown. Where land is kept in grass for a number of consecutive years, top-dressing with lime or, preferably, wood ashes may possibly be advisable in some instances, particularly if ordinary commercial fertilizers are employed in lieu of stable manure. If home-mixed dressings containing basic slag meal or liberal amounts of bone are used with nitrate of soda or nitrate of potash, the need of liming is much less than under many other circumstances.

WHEN TO APPLY LIME.

Lime in the form of carbonate of lime, as in marl, wood ashes, etc., can usually be applied with safety in the spring or at any other season of the year, but autumn is always the safest time to apply caustic or slaked lime. The latter form upon further exposure to the air changes gradually into the mild carbonate of lime, but usually a considerable quantity has not reached that stage when applied, and it may in consequence act too energetically. This is particularly true if the soil is light and sandy, and if plants, which are but little helped by lime, are employed. On very acid soils, particularly such as contain much humus, there is little or no danger from applying reasonable quantities of lime in the spring. If caustic or slaked lime is applied in excessive amounts it may not only injure plants directly, but also indirectly by rendering the texture of the soil unfavorable: it may also make the soil temporarily so alkaline as to interfere with the activity of the organisms which transform ammonia into readily assimilable nitrates. Injury thus arising cannot ordinarily be of long duration, for the reason that the carbonic acid of the soil changes the caustic lime rapidly into carbonate of lime, and thus the alkalinity of the soil is soon reduced.

HOW TO APPLY LIME.

Some writers recommend that upon old mossy meadows and pastures lime should be applied to the surface before plowing, in order that it may help to quickly decompose the organic matter. The chief objection to this procedure is that the lime does not become well incorporated with the soil, and since some of it is turned to the bottom of the furrow and its tendency at all times is to work downward, it may be quickly carried not only away from the surface soil, but also from the reach of plants. The practice of liming such soils immediately after plowing and then thoroughly harrowing has been attended by excellent results. This is particularly the case provided a second application is made in a similar manner just previous to re-seeding. Under such a plan some lime becomes intimately mixed with the entire mass of soil by the operations of tillage, and finally a considerable amount is left near the surface, thus accomplishing two important objects.

In some sections where marl is used extensively it is spread upon the surface and plowed under, turning a furrow about two inches deep. The more common method where marling is practiced is to plow the land and then cart on the marl, dumping it in heaps at such intervals that it can be spread conveniently with a shovel. If the marl is not sufficiently fine, but is of such a nature that it crumbles upon exposure to the air, the heaps may be allowed to remain for some time before spreading, and still further time may be allowed to elapse before the operation of harrowing is begun. Sometimes a "clod crusher" or "bush harrow" may be employed to advantage to break up the lumps before harrowing. A most important point to be observed in applying lime of all kinds is to mix it with the soil as thoroughly as possible, the finer the particles the better being the result.

Pulverized burned lime, or lime which is already slaked, may be spread upon the soil directly from wagons or carts, or dumped in heaps and then spread with a shovel, though the most satisfactory plan in such cases is to employ an ordinary grain drill with fertilizer attachment or a lime spreader. In the use of such spreaders it is generally advisable to attach some burlap or old bagging to the sides and rear of the machine in such a way that it will trail upon the ground. If the machine is so equipped and the burlap is weighted with a piece of wood at the rear, much of the unpleasantness connected with spreading lime is avoided. For those familiar with the nature of lime and its use it is unnecessary to state that it is well, if possible, to apply it on a quiet day. The eyes may be protected by glasses and the nostrils and mouth by devices used by those who run thrashing machines.

The only other form of lime in connection with the application of which any particular difficulty might be encountered is quick or burned lime in lump form. Where only small quantities of such lime are to be used it is frequently immersed for a moment in water, in a basket, and emptied into a wagon body. The following day it will be slaked sufficiently for use. Where larger quantities are used, and a lime spreader is at hand, the lime is sometimes water slaked in large piles on the border of the field and then distributed. To accomplish the water slaking in a satisfactory manner, from 2 to 2½ pails of water should be sprinkled over each cask of lime as it is emptied upon the pile, and finally the whole mass should be very thoroughly covered with soil. In a few days practically all of the lime will be in a fine condition suitable for spreading. In loading it into the spreader care should be taken to first remove the oil, so as to avoid its clogging the machine. If the lime spreader itself is not fitted with a screen, the lime should first be carefully screened for the purpose of removing any hard lumps which may remain, due to imperfect slaking or burning. These lumps may be further slaked by themselves.

A practice preferred by many, and probably the most feasible one where a lime spreader is not to be had, is to place the burnt lime in piles of from 35 to 40 pounds each at suitable intervals (heaps of this size 20 feet apart in each direction furnish about 2 tons per acre), and cover the piles with moist earth. In a few days the lime is so thoroughly slaked that it can be spread directly with a shovel. Provided the soil is dry, from one-fourth to half a pail of water (or in extreme cases even more) should be sprinkled over each pile immediately before it is covered with earth. In this case, as in all others where slaked lime is employed, it is important that it be harrowed into the soil immediately after spreading. In no case should it be exposed long to the air before harrowing, as it is liable to cake and form a sort of mortar to such an extent that it is impossible to mix it as thoroughly with the soil as before.

FORMS OF LIME USED FOR AGRICULTURAL PURPOSES.

Caustic ("quick" or "burnt") lime obtained by burning oyster shells, limestone, etc., is the most economical form in which lime can be bought, in all cases where the distance of railway transportation or of cartage is great. One hundred pounds of such lime usually contain about 95 pounds of actual lime. Sometimes burned lime contains considerable magnesia, a point which has already been considered.

According to Roberts, "when first moved from the kiln, lime weighs about 75 pounds to the heaped bushel; that from shells weighs less than that from limestone. A ton of limestone converted into caustic lime (CaO) weighs between 1,100 and 1,200 pounds; hence it is economy to burn the lime near where the stones are quarried, since it weighs but three-fifths as much as limestone. In slaking, lime takes up considerable quantities of water; hence a ton of slaked or hydrated lime contains really but three-fourths as much lime as a ton unslaked. A heaped bushel of unslaked lime makes 1½ bushels of slaked lime;* therefore it should be transported before it it slaked. When caustic lime is exposed to the air for some time it absorbs both moisture and carbon dioxid from the atmosphere and becomes air-slaked lime. By still longer exposure it may all change into carbonate of lime, the same form as before burning. It is, however, much finer than ground limestone." Lime made from oyster shells and magnesian limestone weighs less per bushel than that made from the purer kinds of limestone.

Gypsum, or Land Plaster, is a combination of lime with sulphuric acid (oil of vitriol) and water. Upon heating, gypsum loses its water and is changed into plaster of Paris or

* A bushel of air-slaked lime is usually considered to weigh 50 pounds.

calcined plaster, which is used in making casts and for many other industrial purposes.

In case a soil is seriously deficient in lime, gypsum may act as a direct manure; usually, however, its beneficial effect upon soils is attributed to its indirect action in liberating potash, and possibly other substances, which were locked up in the soil in such combinations that plants could not make use of them. Gypsum may be helpful to a limited extent on clayey soils by flocculating the fine particles, on account of which the soil is less likely to become "water-logged" and to cake, and hence interfere with the operations of tillage. In the last-mentioned respect water-slaked lime or the carbonate is said to be much more efficacious than gypsum, though as a liberator of potash gypsum is claimed to lead.

It is stated on good authority that, in the presence of decaying organic matter, gypsum may be changed into carbonate of lime. While this may be true under certain circumstances, in experiments at the Rhode Island Station on a soil exceptionally rich in humus and containing a moderate amount of plant residues which were undergoing decomposition, such a change did not result, if at all, to a practical extent. For this reason and on account of the fact that gypsum contains only about one-third as much lime as burned lime, and usually costs as much or more per ton, it cannot take the place of the latter for most of the purposes for which lime is applied to land.

For use in renovating "black alkali" (sodium carbonate) soils in the arid regions, gypsum, as already explained, performs a valuable function which can not be filled by any of the other compounds of lime.

Chalk is a naturally occurring form of carbonate of lime which is exceptionally pure. It is quite soft, and is frequently referred to as marl.

Marl is a name which is applied to earthly deposits usually more or less friable in their character and containing carbonate of lime in quantities ranging usually from 5 to 95 pounds per 100 pounds of the material. It must be evident, therefore, that if one intends to make use of a given deposit of marl for the lime contained in it, he should first have a sample of it analyzed.† If the material will not effervesce upon the addition of either hot or cold vinegar, it probably contains but little carbonate of lime and may be of doubtful value. This test, however, should precede, and not be substituted for, a careful chemical analysis.

On account of the varying chemical composition of marl, it must be obvious also that no definite rules as to the amounts which should be used in given cases can be stated. On a soil

† The Experiment Stations in the different States would probably undertake to do this free of cost.

where one has reason to think a ton of burnt lime should be applied per acre, about 4 tons of a marl containing from 20 to 25 per cent. of actual lime (calcium oxid) should be employed. If the marl is twice as rich the amount applied should be but two tons, etc.

Marls vary somewhat in their physical characteristics, depending upon the amounts and character of the earthly material associated with the carbonate of lime. If the marl is associated with clay it is exceptionally well adapted for use on sandy soils, since the clay and carbonate of lime both tend to make such soils more compact and retentive of manures and moisture. A marl containing sand would, on the other hand, be better suited to clayey soils. According to Heinrich, sand marl may be applied to the soil immediately, but clay marls sometimes contain injurious compounds of iron and sulphur, in which case it is not safe to use them until they have been composted for two or three years, or long enough to effect the decomposition of the iron compound.

Some so-called marls contain considerable quantities of phosphoric acid and potash in such forms as to greatly enhance their fertilizing value.

Phosphate of Lime is found as bone, guano, apatite, and in the form of the well known South Carolina, Florida, and Tennessee phosphate rock. The better classes of phosphate rock contain but small quantities of carbonate of lime, while others contain large amounts. The latter are unfitted on this account for superphosphate manufacture. Both classes of phosphate, when ground finely, have been found to be more or less effective upon acid soils, particular attention having been devoted to their employment on acid muck or peat soils. These phosphates not only seem to materially reduce the acid character of such soils, but after having been in contact with them for some time the assimilability of the phosphoric acid seems to materially increase. The lower-grade phosphates containing considerable quantities of carbonate of lime are particularly effective upon acid soils.

In employing undissolved phosphate rock upon acid soils, certain authorities recommend following the application of the phosphate at an interval of some months, or, if possible, a year, with a dressing of lime. This seems to be a reasonable recommendation provided the plants to be grown are not injured by soil acidity.

Superphosphates, which are prepared by treating phosphate rock, bone, and boneblack with sulphuric acid, generally have about one-third of their lime combined with phosphoric acid and two-thirds with sulphuric acid. The lime combined with sulphuric acid is nothing more nor less than gypsum (land plaster). For this and other reasons superphosphates may not work as well on acid muck or peat soils as ordinary undissolved phosphate rock or ground bone, and if, as is sometimes the case, a slight excess of sulphuric acid is present they may even have a temporary injurious action upon upland soils which are deficient in carbonate of lime.

Basic Slag (Thomas Slag or Slag Meal) is a waste product obtained in the manufacture of steel. It contains relatively more lime than the ordinary high-grade phosphates, and the phosphoric acid in most cases (a few works have put an inferior product on the European market) is possessed of a high degree of assimilability. This product is as yet too little known in this country, and if sold here as cheaply as it might be it would doubtless prove of great value to our agriculture. It is an effective source of phosphoric acid for use upon all kinds of soils, and on account of its high percentage of lime it is of special promise in the reclamation not only of acid upland soils, particularly if rich in organic matter, but also of marsh or muck soils.

Unleached Wood Ashes contain about 35 pounds of actual lime (calcium oxid) in every hundred, 3 tons being, therefore, a little more than equivalent, in lime, to 1 ton of burned lime. They also contain from 5 to 7 per cent. of potash, 1 to 2 per cent. of phosphoric acid, and from 3 to 5 per cent. of magnesia. This latter ingredient, though usually ignored, is of approximately as much value as lime on acid soil. Soils are sometimes deficient in magnesia, and when this is the case the magnesia applied in ashes has a direct manurial action.

Leached wood ashes contain usually less than 1 per cent. of potash and rather more lime than unleached ashes. Frequently they are sold in a wet condition, which, of course, lessens the quantity of actual lime present in a ton.

Limekiln ashes often contain approximately 40 per cent. of lime, and when wood is employed in the burning instead of coal they sometimes contain 2 per cent. or more of potash.

Finely Ground Limestone and Oyster Shells can be used to advantage, if obtainable, especially upon sandy soils. They are not as efficacious as after burning upon heavy clay soils, and such soils as are very acid and contain large amounts of sour humus. This is for the reason that they are not so active chemically, and they cannot be reduced to so fine a state before burning as afterwards.

Dye-house Lime usually contains only a small percentage of lime, and if moist cannot be transported long distances at a profit. A rule that applies well to this and all other waste products of a similar character is not to use them until they have been subjected to chemical analysis, for by changes in the processes of manufacture their value may be materially influenced and substances injurious to vegetation may have found access to them.

Gas-house Lime.—It is never safe to use this substance until it has first been allowed to weather for several months. On acid soils such lime is less effective than burned lime, wood ashes, and limekiln ashes. Owing to recent changes in the process of gas manufacture, lime is used less than formerly.

Waste Lime from Beet-sugar Factories may be effectively applied to soils after it has been allowed to dry. It contains some potash, phosphoric acid, and nitrogen, which still further increase its value. If this material is applied to the soil in a wet condition it tends to cake in the same manner as water-slaked lime does when not immediately worked into the soil. It is sometimes put in piles by itself and worked over every few weeks. It may also be dumped in the field during the winter in small piles, where it is allowed to remain until spring, when, after drying sufficiently, it may be spread and incorporated with the soil. According to Heinrich, this material contains: Water, 35 to 60 per cent.; nitrogen, 0.1 to 0.4; potash, 0.1 to 0.3; phosphoric acid, 0.5 to 1.5, and lime, 15 to 30 per cent. It is evident that this waste material in its moist condition could not be transported to any considerable distance at a profit, and in this country, where labor is such an important item, it would not pay to shovel it over much in order to get it into condition to use.

Waste Lime from Soda-ash Works usually contains considerable water, and can for this reason only be employed to advantage where the cost of transportation is small. If some economical means of drying it could be devised, the range of distance to which it could be profitably shipped would be much increased.

From the preceding statements regarding the different kinds of lime used for agricultural purposes, it is evident that it is impossible to state definitely for all locations and conditions which kind is most economical to employ. This is still more evident when one considers that the character of the soil and of the crop to be grown, as well as the market prices, must be taken into account. Caustic or quick lime is the most concentrated, and consequently the most economical to handle. Its caustic properties, however, render it more vigorous in its action than the milder sulphate (gypsum) or carbonates (limestone, chalk, wood ashes, marl, etc.), and thus better suited for application to soils which are rich in organic matter than to light soils deficient in this substance. It is also specially suited to correcting acidity in sour soils. There may be special reasons in particular cases why some of the other compounds of lime are preferable to quicklime. Gypsum has been used in agriculture to a considerable extent with very satisfactory results. On account of its peculiar composition it has been found especially valuable for neutralizing sodium carbonate (black alkali) in alkali soils. Wood ashes are used extensively in some localities, in many cases as much for the lime as for the potash which they contain. It is very doubtful, however, whether it would not be more economical at the present prices of wood ashes and caustic lime to employ the latter in many cases, supplementing the lime with potash salts and other fertilizing materials if the latter are required by the soil.* The item of transportation is also decidedly in favor of the use of lime and agricultural chemicals as substitutes for ashes.

SUMMARY.

The use of lime as a soil improver is very ancient, and its value for this purpose is generally recognized. Its action as a fertilizer is both direct and indirect.

There are many soils in which lime is deficient, notably such as are derived from granite, mica-schist, and certain sandstones, slates, and shales. On such soils lime is often of direct value in supplying a necessary element of plant food.

The indirect value of lime is perhaps more important than its direct action, because probably the majority of cultivated soils contain sufficient lime to meet the direct demands of plants for food. Lime is of indirect value in unlocking the unavailable potash, phosphoric acid, and nitrogen in the soil.

Lime exerts a decided influence on the mechanical condition of soils, rendering heavy compact soils looser in texture and tending to bind particles of loose leachy soils.

Lime is also beneficial in furnishing conditions in the soil favorable to the activity of the micro-organisms which convert the nitrogen of organic matter into nitrates which are readily assimilated by plants, which decompose organic matter, and which assist certain leguminous plants to assimilate the free nitrogen of the air.

Lime is also beneficial in furnishing conditions in the soil favorable to the activity of the micro-organisms which convert the nitrogen of organic matter into nitrates which are readily assimilated by plants, which decompose organic matter, and which assist certain leguminous plants to assimilate the free nitroen of the air.

One form of lime, gypsum, has been shown to be a most effective corrective of black alkali, found in some of the soils of the arid portions of the United States.

The continued use of lime unaccompanied by other fertilizers may prove injurious, especially on poor soils, since it converts the insoluble nitrogen, potash, and phosphoric-acid compounds of the soil into such as can be rapidly taken up by plants or washed out in the drainage, thus hastening the exhaustion of the supply of these substances in the soil. As the German adage states, "The use of lime without manure

* U. S. Dept. Agr., Farmers' Bul. 65, p. 24.

makes both farm and farmer poor." If the soil is not abundantly supplied with organic matter, its retentive power for water and fertilizers may be seriously reduced on account of the destruction of the organic matter by the action of too much lime. Soils may sometimes be injured by applications of impure forms of lime, which harden like cement in the soil, or of those which contain an excessive amount of magnesia.

It has been shown that even upon many upland and naturally well-drained soils apparently in good condition otherwise, the sourness (acidity) is so great that most varieties of plants will not thrive. Lime is the most economical and effective substance thus far used for correcting this condition. According to experiments made by the Rhode Island Agricultural Experiment Station on acid soils in that State, the plants tested may be classified with regard to their behavior toward lime as follows: *Plants benefited by liming*—spinach, lettuce (all kinds), beets (all kinds), okra (gumbo), salsify (vegetable oyster), celery, onion, parsnip, cauliflower, cucumber, egg-plant, cantaloupe, asparagus, kohl-rabi, cabbage, dandelion, Swedish turnip, pepper, peanut, English or flat turnip, upland cress (pepper grass), martynia, rhubarb, common pea, pumpkin, summer squash (scalloped), golden wax bean, red Valentine bean, horticultural pole bean, bush Lima bean, lentil, Hubbard squash, saltbush, hemp, tobacco, sorghum, alfalfa, clover (red, white, crimson, and alsike), barley, emmer, wheat, oats, timothy, Kentucky bluegrass, Canada pea, Cuthbert raspberry, gooseberry, currant (White Dutch), orange, quince, cherry, Burbank Japan plum, American linden, American elm, sweet alyssum, mignonette, nasturtium, balsam, pansy, poppy, and sweet pea; *plants but little benefited by liming*—Indian corn, spurry,* rye, carrot, chicory, Rhode Island bent, and redtop; *plants slightly injured by liming*—cotton, tomato, cowpea, zinnia, phlox (Drummondi), Concord grape, peach, apple, and pear; *plants distinctly injured by liming*—lupine, common sorrel *(Rumex acetosella)*, radish, velvet bean, castor bean, flax, blackberry, black-cap raspberry, cranberry, Norway spruce, and American white birch. Other plants said to be injured are the chestnut, azalea, and rhododendron.

Many kinds of lime are available for agricultural use, among which are caustic or burnt lime, or quicklime, which should contain at least 90 per cent. of actual lime (CaO) and is the most concentrated form of this material; gypsum, or land plaster, in which the lime is in the form of the mild sulphate; ground limestone and chalk, in which the lime is in the form of the mild carbonate; different kinds of marl, containing varying proportions of sand and clay and from 5 to 95 per cent.

* It has been reported in England that spurry is injured by liming, but such results have not been obtained in Rhode Island.

of carbonate of lime; wood ashes, which contain from 30 to 35 per cent. of lime in the form of carbonate; limekiln ashes, containing about 40 per cent. of lime; and waste lime from gas houses, sugar-beet factories, etc., the composition of which varies with the process of manufacture.

It is impossible to state definitely for all locations and conditions what kind of lime is cheapest to use. Caustic or quick lime is the most concentrated and consequently the most economical to handle. On account of its caustic properties it is more vigorous in its action than the milder sulphate (gypsum) or carbonate (limestone, chalk, wood ashes, marl, etc). There may be special reasons, however, why some of the latter may be preferable. For instance, gypsum, on account of its peculiar composition, has been found to be a specially valuable corrective of black alkali.

The frequency with which liming should be practiced depends, among other things, upon the character of the soil and the rate of application, the number of years involved in the rotation practiced, the plants grown and their order of succession. As a general rule, it may be stated that from ½ to 1½ tons of lime per acre every five or six years is sufficient. Applications of 2 or 3 tons may, however, be advisable in cases of very acid soils, which are to be seeded down and are to remain in grass for several years. The practice of applying small amounts of lime at somewhat frequent intervals is being generally accepted as preferable to the use of large amounts at rare intervals.

Lime combined as carbonate, as in marl, wood ashes, etc., can usually be applied with safety in the spring or at any other season of the year, but autumn is always the safest time to apply caustic or slaked lime. It is generally considered best to apply the lime to the soil immediately after plowing and harrow it in thoroughly. Lime which is already slaked may be spread upon the soil directly from wagons or carts, or dumped into heaps and then spread with a shovel, although the most satisfactory plan in such cases is to use a lime spreader or ordinary grain drill with a fertilizer attachment. Where a lime spreader or similar implement is not available the burnt lime may be placed on the soil in piles of from 40 to 50 pounds each, covered with moist earth, and allowed to slake before being spread with a shovel. Marls frequently contain injurious compounds and should therefore be allowed to weather for some time in the field before being incorporated with the soil. The same is true of gas-house lime, which is impregnated with sulphur compounds which are injurious to plants.

In conclusion it may be said, ascertain first whether lime is needed. If it is, apply it judiciously, and never depend upon lime alone to maintain the fertility of the soil, for all of the ingredients which plants need must be present in the soil to insure the profitable production of crops.

DENATURALIZED ALCOHOL.

HOW THE OPERATION IS PERFORMED IN GERMANY.

Consul-General Thackara, of Berlin, writing on the use of denaturalized alcohol in Germany for technical purposes, says that the subject was ably and exhaustively treated by his predecessor, Consul-General Mason, in various reports on the subject. He gives the following extract from one of Consul-General Mason's reports regarding the methods in use in Germany for the denaturalization of alcohol:

For most industrial purposes alcohol is used in Germany duty free, after having been "denaturalized" or rendered unfit for drinking purposes by admixture, in presence of a government official, with a prescribed percentage or proportion of one or more of several different substances prescribed in the very elaborate statute which governs the complicated subject in Germany. There are two general classes or degrees of denaturalizing, viz., the "complete" and the "incomplete," according to the purposes for which the alcohol so denaturalized is to be ultimately used.

METHODS OF DENATURALIZING.

1. Complete denaturalization of alcohol by the German system is accomplished by the addition to every 100 liters (26½ gallons) of spirits: (*a*) Two and one-half liters of the "standard denaturalizer," made of 4 parts of wood alcohol, 1 part of pyridin (a nitrogeneous base obtained by distilling bone oil or coal tar), with the addition of 50 grams to each liter of oil of lavender or rosemary; (*b*) one and one-fourth liters of the above "standard" and 2 liters of benzol, with every 100 liters of alcohol.

Of alcohol thus completely denaturalized there was used in Germany during the campaign year 1903-4, 931,406 hectoliters denaturalized by process (*a*), as described above, and 52,764 hectoliters which had been denaturalized by process (*b*). This made a total of 26,00,505 gallons of wholly denaturalized spirits used during the year for heating, lighting, and various processes of manufacture.

2. Incomplete denaturalization, i. e., sufficient to prevent alcohol from being drank, but not to disqualify it from use for vari-

ous special purposes, for which the wholly denaturalized spirits would be unavailable, is accomplished by several methods, as follows: The quantity and nature of each substance given being the prescribed dose for each 100 liters (26½ gallons) of spirits. (*c*) Five liters of wood alcohol or one-half liter of pyridin (*d*) 20 liters of solution of shellac, containing 1 part gum to 2 parts alcohol of 90 per cent. purity (alcohol for the manufacture of celluloid and pegamoid is denaturalized); (*e*) by the addition of 1 kilogram camphor or 2 liters oil of turpentine, or one-half liter benzol to each 100 liters of spirits.

Alcohol to be used in the manufacture of ethers, aldehyde, agarcin, white lead, brom-silver gelatins, photographic papers and plates, electrode plates, collodion, salicylic acid and salts, aniline chemistry, and a great number of other purposes, is denaturalized by the addition of (*f*) 10 liters sulphuric ether, or 1 liter of benzol, or one-half liter oil of turpentine, or 0.025 liter of animal oil.

For the manufacture of varnishes and inks alcohol is denaturalized by the addition of oil of turpentine or animal oil, and, for the production of soda soaps, by the addition of 1 kilogram of castor oil. Alcohol for the production of lanolin is prepared by adding 5 liters of benzine to each hectoliter of spirits.

The price of denaturalized alcohol varies in the different states and provinces of the Empire in accordance with the yield and consequent market price of potatoes, grain, and other materials. At the present time alcohol of 95 per cent. purity, which is the quality ordinarily used in Germany for burning, sells at wholesale from 28 to 29 pfennigs (6.67 to 6.9 cents) per liter (1.06 quarts), and at retail for 33 pfennigs (7.85 cents) per liter.